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THE FLOW OF WATER IN OPEN CANALS.

Translated from Sonnet's "Dictionnaire des Mathematiques Appliquées.

The motion is supposed to be in a *permanent* condition; but it may be uniform or varied.

I. The various fluid threads parallel to the general direction of motion do not have the same velocity; those in contact with the sides experience a resistance which retards them, in their turn they retard adjacent filaments, and so on; so that the maximum is near the surface, and towards the middle of the stream. Usually these differences are not regarded; but account is taken of the mean resistance—that is, that which multiplied by the transverse section gives the effective discharge, or the volume of liquid passing this section in a unit of time. This mean resistance U, according to Dubuat, is given by the formula

$$\frac{U}{V} = \frac{V+2.37}{V+3.15} \qquad (1.)$$

In ordinary cases we may take U = 0.80 V. But in case of great depth of stream, the co-efficient 0.80 diminishes to 0.75 and even to 0.62, and when the bottom is covered with rushes it reaches 0.60 and less. According to experiments of Dubuat, W being the velocity at the bottom or near the side,

$$U = \tfrac{1}{2}(V + W) \qquad (2.)$$

which gives if U = 0.80 V,

$$W = 0.60\ V, \text{ and } V + U = 1.33\ W.$$

In canals it is not necessary that the velocity at the bottom should exceed a certain limit; that being exceeded, the ground at bottom is disturbed.

Experience has furnished the following table:

Table of limiting values of W *and* U.

	W.	U.
Soft earth	0.076 m.	0.101 m.
Weak clay	0.152	0.203
Sand	0.305	0.407
Gravel	0.609	0.812
Cobbles	0.614	0.819
Broken stone	1.220	1.630
Schist	1.520	2.026
Stratified rock	1.830	2.440
Hard rock	3.050	4,066

Of course these must not be regarded as absolute values; besides, formula (2) of Dubuat is not rigorous, divers considerations leading to the conclusion that it is not exact, and that in case of water of great width compared with depth

$$U = \tfrac{1}{3}(2\,V + W) \qquad (3.)$$

As W lies between O and V the ratio $\frac{U}{V}$ would lie between $\frac{2}{3}$ and 1, giving a mean value of 0.833, which agrees with the mean results of observations. Another reason may be given for preferring (3) to (2). M^r. Defontaine made a series of experiments on a branch of the Rhine, according to which the law of decrease of velocity at the middle of a stream is given in the formula

$$V = 1^m.266 - 0.25247\,y^2;$$

V being the velocity at the depth y. For $y = 1^m.50$ we find $W = 0^m.698$. This

value is little more than half the velocity 1m.266 at the surface; substituted in formula (3) we have $\frac{U}{V} = 0.85$; a little more than (1).

II. Uniform Motion.—When the course of the water is in a right line, the transverse section being constant, and the slope being suitable, the motion may be uniform. This is generally the case in canals, and occurs often in rivers or in portions of them. The relation between the mean velocity, the slope, the section, and the wet perimeter, is easily deduced.

Let us consider a section comprised between any two transverse sections A B and C D.

Let g and g' be their centres of gravity, z the difference of level of these centres, L the distance between the sections, P the mean pressure per square metre in the section A B, P′ that in the section C D. Let p be the weight of a cubic metre of water.

The motion being supposed uniform, the threads move parallel to the bed, each with a constant velocity; the transverse section is constant; designate it by O, and the wet perimeter by K. Suppose that in a very short time t, the fluid mass, is slightly displaced; that the molecules which were in the section A B have arrived at and distributed themselves upon a curved surface A′ B′, and those that were in C D, upon C′ D′. Each filament having a uniform velocity, there is no change in the quantity of motion; it follows that if all forces acting on the fluid are projected along the direction of the current, the algebraic resultant or sum must be equal to zero. The pressure acting upon A B is a normal force equal to P O; that upon A′ B′ is P′ O; but P = P′; for, the motion being uniform, the pressures are determined by the laws of hydrostatics, and the pressures are equal, since the atmospheric pressures at A and C are equal. The two projections, therefore, vanish in the resultant. The weight of the fluid A B C D is p O L; this vertical force makes with the direction of the current an angle whose cosine is $\frac{z}{L}$. Hence the projection is

$$p \text{ O L} . \frac{z}{L} \text{ or } p \text{ O } z.$$

The normal reactions of the sides do not give projections, and the mutual reactions of the threads vanish in the resultant, being equal and opposed. The longitudinal resistance of the bed remains to be determined. Experience has shown that this resistance is proportional to the area of the wetted wall, that is to k L, and also to a function of the mean velocity which we shall represent by ϕ (U): the resistance then has an absolute value K L ϕ (U): hence

$$p \text{ O } z - \text{K L } \phi(\text{U}) = 0,$$

or

$$\frac{\text{O}}{\text{K}} \cdot \frac{z}{\text{L}} = \frac{1}{p} \phi(\text{U}).$$

The ratio $\frac{\text{O}}{\text{K}}$, of section to wet perimeter, has been called the *mean radius*, and it is usually denoted by R. The ratio $\frac{z}{\text{L}}$ between the difference in level of the centres of gravity and the distance between the sections, the *slope per metre*, is denoted by the letter I. The number p is sensibly 1,000. The above may therefore be written

$$\text{R I} = 0.001 \, \phi(\text{U}) \qquad (4.)$$

III. M. de Prony has adopted for the function 0.01 ϕ (U) the form a U + b U^2, and to satisfy the experiments of Dubuat, 31 in number, he assigns to the coefficients a and b the values $a = 0.000044$ and $b = 0.000309$.

Later, Eytelwein, adding to Dubuat's experiments those of Brunnings, Woltmann, and Funek, derived from 91 experiments the values $a = 0.000024$, and $b = 0.000366$.

M. de Saint-Venant has proposed for the same function another form, and he puts

$$\text{R I} = \cdot 000401 \, . \, \text{U}^{\frac{2}{1+\frac{1}{4}}}. \qquad (5.)$$

The following table gives values corresponding to the formulas of Eytelwein and Saint-Venant.

U.	A u + B u^2.	0.000401 U$^{\frac{2}{1+\frac{1}{4}}}$.
m.		
0.05	0 0000021	0.0000013
0.10	0.0000061	0.0000049
0.15	0.0000118	0.0000107
0.20	0.0000194	0.0000186
0.25	0.0000289	0.0000284
0.30	0.0000401	0.0000403
0.35	0.0000532	0.0000541
0.40	0.0000682	0.0000697
0.45	0.0000849	0.0000873
0 50	0 0001035	0.0001068
0.55	0 0001239	0.0001281
0.60	0.0001462	0.0001512
0.65	0.0001701	0.0001762
0.70	9.0001960	0.0002030
0.75	0.0002239	0.0002316

U.	$A u + B u^2$	$0.000401 U^{\frac{3}{2}}$
m.		
0.80	0.0002534	0.0002619
0.85	0.0002848	0.0002941
0.90	0.0003181	0.0003280
0.95	0.0003531	0.0003636
1.00	0.0003900	0.0004010
1.05	0.0004287	0.0004402
1.10	0.0004693	0.0004810
1.15	0.0005116	0.0005237
1.20	0.0005558	0.0005680
1.25	0.0006019	0.0006140
1.30	0.0006497	0.0006618
1.35	0.0006994	0.0007112
1.40	0.0007510	0.0007623
1.45	0.0008043	0.0008151
1.50	0.0008595	0.0008697
1.55	0.0009165	0.0009258
1.60	0.0009754	0.0009837
1.65	0.0010360	0.0010432
1.70	0.0010985	0.0011044
1.75	0.0011629	0.0011672
1.80	0.0012290	0.0012317
1.85	0.0012970	0.0012978
1.90	0.0013669	0.0013656
1.95	0.0014385	0.0014350
2.00	0.0015120	0.0015062
2.05	0.0015873	0.0015788
2.10	0.0016645	0.0016532
2.15	0.0017434	0.0017291
2.20	0.0018242	0.0018067
2.25	0.0019069	0.0018859
2.30	0.0019913	0.0019667
2.35	0.0020776	0.0020492
2.40	0.0021658	0.0021332
2.45	0.0022557	0.0022189
2.50	0.0023475	0.0023061
2.55	0.0024411	0.0023949
2.60	0.0025366	0.0024853
2.65	0.0026338	0.0025774
2.70	0.0027329	0.0026710
2.75	0.0028339	0.0027663
2.80	0.0029366	0.0028631
2.85	0.0030412	0.0029615
2.90	8.0031477	0.0030615
2.95	0.0032559	0.0031631
3.00	0.0033660	0.0032661

Other values of R I have been proposed. The Italian engineers use the simple formula $0.0004\ U^2$, which differs but slightly from that of M. de Saint-Venant. This may be employed when one has need only of an approximation, and rapidity of operation is desirable. But in the majority of instances the use of the table is preferable.

IV. By means of the above table various problems may be solved. (1.) Given slope and section, the discharge may be determined. Knowing the section, and therefore the wet perimeter, the mean radius is deduced. The first member of equation (4) is now known. The table gives the mean velocity U; multiplying by the section, the discharge is found. For example, let

$$I = 0.0008\ ;\ O = 6^{mq},\ X = 3^m.60.$$

Then

$$R = \frac{6}{3.60} = 1.6667. \quad \therefore RI = 1.6667 \times 0.0008 = 0.0013\,3.$$

From the table, by interpolation, from column $a\,U + b\,U^2$, $U = 1^m.876$.

Hence

$$Q = 6^{mq} \times 1^m.876 = 11^{mc}.256.$$

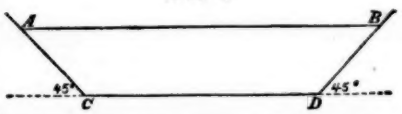
(2.) Given section and discharge to find the slope. The mean radius is found from the section. The discharge divided by the section gives U, the mean velocity. The table gives the value of $a\,U + b\,U^2$, or of R I.; dividing by R we find the required value of I. Suppose a canal of 10^{mq} section, and 7^m wet perimeter, to discharge $5^{m\,cub}$ in a second

$$R = \frac{10^{mq}}{7};\ U = \frac{5}{10}.^m$$

From the table we find $a\,U + b\,U^2 = 0.0001035$. Dividing by $\frac{10}{7}$, we find $I = 0.0007255$.

(3.) Given slope and discharge, to find section. In this case, the transverse section being known, the problem is to find the *water-line;* that is the intersection of this indefinite transverse section with the plane forming the upper level of the water. Generally this is found by trial. A hypothesis is made as to the position of the water line; the discharge is found from given section and slope. If this discharge exactly equals the given discharge, the water-line is that assumed otherwise, by repeated trials the proper line will be found. Suppose the slope $= 0.0005$, the discharge $12^{m\,cub}$, and that the section of the bed has a horizontal base of 4^m and sides inclined 45°.

FIG. 1.



Let A B (Fig. 1) be the water-line, 2^m above bottom.

$$A\,B = C\,D + 2^m \times 2 = 8^m.$$

The area of the trapezium is

$$2 \times \frac{8+4}{2} = 12^{mq}$$

The value of the wet perimeter is

$$4 + 2\sqrt{2} \times 2 = 9.^m656.$$

Hence

$$R = \frac{12}{9.656} = 1.2427,$$

and

$$RI = 1.2427 \times 0.0005 = 8.00062135.$$

The value of $a\,U + b\,U^2$ according to the table gives $U = 1.^m27$. Hence $Q = 12^{m\,q} \times 1.27 = 15.^{m\,c}24$; a quantity larger than the given discharge. The assumed value of the water-line must be diminished. Suppose it $1.^m80$ above bottom, then

$$O = 1.80 \cdot \frac{4 + 1.8 \times 2 + 4}{z} = 10.^{m\,q}44$$

$$K = 4 + 2 \times 1{,}8\sqrt{2} = 9^m.0904$$

$$R = \frac{10.44}{9.0904} = 1.1483;$$

$$RI = 1.1483 \times 0.0005 = 0.00057415.$$

By the table $U = 1.^m22$; hence $Q = 10.^{m\,q}44 \times 1.^m22 = 12.^{m\,c}7368$; a value a little too large. By further trials it is found that the height of the water-line is $1.^m743$, corresponding to $O = 10.^{m\,q}01$; $K = 8.^m929$ and $U = 1.^m2072$.

This method by trial must be applied in case of a rectangular section; the section, wet perimeter, and mean velocity are easily expressed in terms of h, the height of the water-line; but the resulting equation is of the 3d degree with reference to h.

V. The application of the principle of the quantity of motion causes the mutual actions of filaments to disappear from the calculation. If regard is had to these, the theorem of work must be applied to the fluid mass. The motion being uniform, the increase of *vis viva* is zero. The works of pressures up and down are equal, and contrary in sign. It follows that the resistance of the bed and of the mutual actions of the threads must be equal and opposed to the work of gravity. For the time t, this is equal to $p\,O\,U\,t\,.\,z$.

From the equation due to the consideration of the quantities of motion

$$p\,O\,z = K\,L\,\phi(U).$$

The work of mutual reactions and of the resistance of the bed is expressed by

$$-K\,L\,\phi(U)\,.\,U\,t.$$

The work of the resistance of the bed regarded separately is

$$-K\,L\,\phi(U)\,W\,t.$$

Hence the work of the mutual actions of the filaments is

$$-K\,L\,\phi(U)\,.\,(U-W)\,t$$

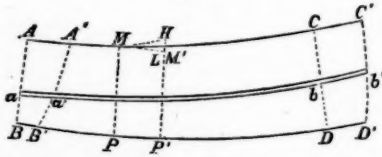
VI. The preceding discussion supposes that the bed of the stream has no marked sinuosities. If the bottom abruptly approaches the water-line as in Fig. 2, at

FIG. 2.

B, the foregoing formulas are not applicable. In this case there is supposed to be a partition B I, and the total stream is regarded as composed of two portions, A B I and I B C D. Formula (4) is separately applied to these; the sum of the results gives the total discharge. This case is sometimes presented in the event of an inundation, or of a stream leaving its bed. It is of course exceptional.

VII. VARIABLE MOTION.—The motion of water in a canal or river cannot be uniform if the section or slope varies; especially if the slope is a counter-slope; that is, if the bed rises going down stream. But in such cases it is supposed that the motion is reduced to some permanent amount. The relation between mean velocity and slope and section is found by applying to a portion of the stream the principle of work. Let A B and C D, Fig. 3, be two sections regarded

FIG. 3.



as sensibly vertical if the surface slope is slight. The filaments crossing the section A B have not the same velocity; let v be the velocity of the filament which passes at a at a distance y below A: and o be the section of the filament. During a very short time t, the volume which has passed through the section is $o\,v\,t$; the mass is $\frac{p\,o\,v\,t}{g}$; p being the weight of a cubic metre of water and its *vis viva* being $\frac{p\,o\,v^3\,\theta}{2\,g}$.

Let A′ B′ be the curved surface to which the liquid molecules have arrived after the time t. The *vis viva* of liquid between A B and A′ B′ is $\frac{p\,t}{2\,g}\,\Sigma\,o\,v^3$; the summation Σ being taken for all filaments crossing the

section A B. For $\Sigma\, o\, v^3$ is generally written $O_0\, U_0^3$, O_0 denoting the area of the section A B, and U_0 the mean velocity in this section. But the product must be multiplied by a coefficient greater than unity, since the first expression is a little larger than the second.

For we have

$$v = U_0 + u,$$

u being the difference, positive or negative, between the mean velocity and the velocity of the filament under consideration. From this relation,

$$o\, v^3 = o\, U_0^3 + 3\, o\, U_0^2\, u + 3\, o\, U_0\, u^2 + o\, u^3$$

$$\Sigma\, o\, v^3 = \Sigma\, o\, U_0^3 + 3\, \Sigma\, o\, U_0^2 u + 3\, \Sigma\, o\, U_0\, u^2 + \Sigma\, o\, u^3;$$

or

$$\Sigma\, o\, v^3 = O_0\, U_0^3 + 3\, U_0^2\, \Sigma\, o\, u + \Sigma\, u^2 o\, (3\, U + u);$$

hence,

$$\Sigma\, o\, v^3 = O_0\, U_0^3 + 3\, U_0\, \Sigma\, o\, u + \Sigma\, u^2\, o\, (2\, U + v).$$

The second term of the second member is zero; for by definition,

$$\Sigma\, o\, v = O_0\, U_0, \text{ or } \Sigma\, o\, U_0 + \Sigma\, o\, u = O_0\, U_0,$$

or

$$O_0\, U_0 + \Sigma\, o\, u = O_0\, U_0.$$

$$\therefore\ \Sigma\, o\, u = 0.$$

Finally,

$$\Sigma\, o\, v^3 = O_0\, U_0 + \Sigma\, u^2\, o\, (2\, U + v).$$

The second term of the second member is essentially positive; consequently

$$\Sigma\, o\, v^2 > O_0 U_0^3.$$

The coefficient 1.1 is generally employed as multiplier of $O_0\, U_0^3$; so that the expression for the *vis viva* of the liquid passing in the time t through the section A B is

$$\frac{1.1\, p\, O_0\, U_0^3\, t}{2\, g}, \text{ or } \frac{1.1\, p\, Q\, t\, U_0^2}{2\, g};$$

denoting the discharge by Q.

Let C′ D′ be the curved surface reached at the end of the time t by the molecules first contained in the section C D; then the *vis viva* of the liquid passing between these two sections in this time is, as above,

$$\frac{1.1\, p\, Q\, t\, U_1^2}{2\, g},$$

U_1 being the mean velocity in the section C D. Again, by reason of the permanence of motion the *vis viva* of the liquid between A′ B′ and C D is the same at the initial instant and at the end of the time t. Hence the total increase of *vis viva* is reduced to the difference of the above expressions, *i. e.*

$$\frac{1.1\, p\, Q\, t}{2\, g_1} (U_1^2 - U_0^2) \qquad (1.)$$

This must be made equal to the sum of the works of the forces acting on the portion of fluid under consideration.

The pressure per square metre on a is $P_0 + p\, y$; P_0 being the atmospheric pressure; for the movement being nearly uniform, the pressure should be determined according to the principles of hydrostatics. The pressure upon the section o is

$$(P_0 + p\, y)\, o,$$

and the work of this pressure is

$$(P_0 + p\, y)\, o.\ v\, t.$$

The sum of the works of the pressures on the section A B is

$$\Sigma\, (P_0 + p\, y)\, o\, v\, t, \text{ or } P_0\, t\, \Sigma\, o\, v + p\, t\, \Sigma\, o\, v\, y.$$

The first term may be written $P_0\, t\, O_0\, U_0$ or $P_0\, t\, Q$. The sum $\Sigma o\, v\, y$ is the sum of the movements of the volumes $o\, v$ with reference to the horizontal plane passing through the point A. If we denote by Y the distance from this plane of the centre of gravity of the volume A B B′A, we have $\Sigma\, o\, v\, y = O_0\, U_0\, Y_0$, and hence

$$p\, t\, \Sigma\, o\, v\, y = p\, Q\, t\, Y.$$

The work of the pressures upon A B is therefore definitely expressed by the formula

$$P_0\, Q\, t + p\, Y_0\, Q\, t.$$

Similarly the work of the pressures on C D is

$$-\ (P_0\, Q\, t + p\, Y_1\, Q\, t)$$

Y_1 denoting the distance of the centre of gravity of the volume C D D′ C′ from the horizontal plane passing through the point C. The algebraic sum of the forces up and down stream, reduces to

$$p\, Q\, t\, (Y_0 - Y_1) \qquad (2.)$$

The work of gravity upon the system under consideration is the same as if the volume A B B′ A′ were directly transported to C D D′ C′. It will be obtained by multiplying the weight of A B B′ A′, *i. e.*, $p\, Q\, t$, by the vertical distance between the centres of gravity of the volumes A A B′ A′ and C D D′ C′. If z denotes the difference of level of the points A and C, that is, the total slope, we have for the required distance

$$z + Y_1 - Y_0.$$

The work of gravity is consequently

$$p\, Q\, t\, (z + Y_1 - Y_0) \qquad (3.)$$

Adding to the work (2) of up and down pressures, we obtain

$$p\, Q\, t\, z \qquad (4.)$$

The normal resistances of the bed do not produce work; that due to longitudinal resistance must be determined. It is assumed that in the case where the motion is sensibly uniform, the resistance of the bed exerted upon a lamina between two transverse sections at a distance ds from each other may be expressed, as in uniform motion, by the function ϕ (U) of the mean velocity multiplied by the area K ds of the wetted surface. Its work, which is negative, is expressed by

$$- K.ds.\phi(U) W t.$$

Substituting in the factor W t, which represents the path described, the velocity at bottom, W, instead of the mean velocity U, we find the total work of resistance of the bed is expressed by

$$-\int_o^s K.ds.\phi(U) U t,$$

s representing the developed length of the base B D. Putting for U its value $\frac{Q}{O}$ in the last factor, we may unite

$$- Q t \int_o^s \frac{K}{O} . \phi(U) ds \qquad (5.)$$

The equation of the work becomes in this case

$$\frac{1.1 p Q t}{2g}\left(U_1^2 - U_0^2\right) = pQtz - Qt\int_o^s \frac{K}{O}\phi(U) ds.$$

whence

$$z = 1.1\left(\frac{U_1^2}{2g} - \frac{U_0^2}{2g}\right) + \int_o^s \frac{K}{O} . 0.0001 \phi(U) ds. \qquad (6.)$$

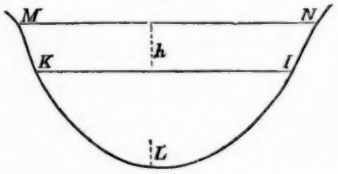
This is the equation of the variable motion of water in canals and rivers.

VIII. To determine the slope z, a certain number of transverse sections must be made, and measured for each area O, for the wet perimeter K, and the mean velocity must be calculated. Then rectangular axes are drawn. For abscissas, are laid off the distances s between the section A B and those measured; for ordinates, are taken the values of $\frac{K}{O} . 0.001 \phi(U)$. A curve is now drawn through the extremities of the ordinates. The area of this curve represents the integral in the second member of the equation. The value of z is then easily found. If we wish to calculate the discharge by means of the same equation, the slope z being given,—we convert U into a function of Q and O and solve the equation with reference to Q.

IX. Another question is often presented in practice, which may be solved by aid of equation (6). Suppose the transverse section constant and its slope uniform; that the discharge is known and the position of the water-line in a certain section, as C D: required the position of the water-line in another section A B. For example, this question has to be solved to determine the effect of a dam and the distance of backwater.

To solve this problem we must, according to M. Belanger, introduce into (6) the slope. Let M K L I N, Fig. 4, be the constant sec-

FIG. 4.



tion of the bed, and K I a fixed horizontal line below the variable water-line M N in all the sections. Denote by x the length M N and by h the distance between M N and K I. Consider any point M, Fig. 3, of the surfaces. Draw through this point a transversal section M P, and draw a section at an infinitesimal distance M' P'. Through M draw the horizontal line M H and the line M L parallel to P P'. We shall have M L = P P' = ds; and if i is the inclination per metre, the triangle H M L gives H L = i. M L = $i\,ds$.

But H L = H M' + M' L; and H M' is the infinitesmal slope dz of the surface between M and M'; M' L is the increase of height of the water line, which may be denoted by dh. Then

$$i\,ds = dz + dh. \qquad (7.)$$

Apply equation (6) between the sections M P and M' P'. For z put dz;

$$\text{for } 1.1\left(\frac{U_1^2}{2g} - \frac{U_0^2}{2g}\right)$$

the differential of

$$1.1\,\frac{U_1^2}{2g}, \text{ i. e. } \frac{1.1\,U\,dU}{g}; \text{ and}$$

for the integral put the quantity under the sign $\int$. This gives

$$dz = 1.1\,\frac{U\,dU}{g} . + \frac{K}{O} . 0.001 \phi(U) ds. \qquad (8.)$$

We can put for $d\,z$ its value derived from (7), giving

$$d\,U = -\,Q\,.\,\frac{d\,O}{O^2}$$

and

$$U\,d\,U = -\,Q^2\,\frac{d\,O}{O^3} = -\,U^2\,\frac{d\,O}{O}$$

But (Fig. 3),

$$d\,O = x\,d\,h.$$

$$\therefore\ U\,d\,U = -\,\frac{U^2\,x\,d\,h}{O}.$$

Using these values, equation (8) becomes

$$i\,d\,s - d\,h = -\,\frac{1.1\,.\,U^2 x\,d\,h}{g\,O} + \frac{K}{O}\,.\,0.001\,\phi\,(U)\,d\,s.$$

Hence

$$d\,s = \frac{1 - 1.1\,.\,\frac{U^2\,x}{g\,O}}{i - \frac{K}{O}\,.\,0.001\,\phi\,(U)}\,.\,d\,h. \qquad (9.)$$

This equation serves to solve the proposed problem. Knowing the value h_1, in a section made a little above the dam, we wish to know at what distance s above this section the height will be reduced to a value h, not exceeding say by more than 1 or 2 centimetres that of the water-line before the erection of the dam. From (9) we get

$$s = \int_{h^2}^{h_1} \frac{1 - 1.1\,\frac{U^2\,x}{g\,O}}{1 - \frac{K}{O}\,.\,0.001\,\phi\,(U)} \qquad (10.)$$

The second member may be calculated by Simpson's formula.

X. Generally we find for s a value larger and larger in proportion as h_0 is less than the height which corresponds to a uniform régime, and which would destroy the denominator of (9):—since in that case

$$\frac{O}{K}\,i = 0.001\,.\,\phi\,(U). \quad \text{See (Eq. 4.)}$$

Then $\frac{d\,h}{d\,s}$ approaches zero, and the surface of the water resulting from the erection of the dam has an asymptotic relation to that due to the uniform motion. But there is an exception: it occurs when among the values between h_0 and h_1 there is one which makes the numerator

$$1 - 1.1\,\frac{U^2\,x}{O\,g}$$

vanish. For this value $\frac{d\,h}{d\,s} = \infty$, a result incompatible with the data of equation (6); showing that the formula fails. This corresponds to a case of *jutting* (ressaut).

The equation for motion of water in open canals was published at about the same time (1828) by M. Belanger and by M. Poncelet. The same subject has been since treated by Navier, Vauthier, and Coriolis, and by M. Bresse in his *Cours de Mécanique Appliquée.*

FOREIGN SCIENTIFIC ITEMS.

From "Engineering," and "Journal of Society of Arts."

ECONOMY OF WATER IN CANALS.

M. de Caligny has during several years past been much occupied in considering the best means of economizing the water in canal locks. He has presented on this interesting question several communications to the Academy of Sciences, and a recent bulletin contains a new note from this gentleman, of which the following is a *resumé.* It is well known that in ordinary locks it is necessary to consume in passing through a boat, whatever may be its size, a volume of water equal to the surface of the lock, multiplied by the difference in level of the two reaches. In 1845, M. de Caligny proposed a system consisting of two locks of the same height and of similar dimensions, in other words, a double lock, between the two chambers of which alternative communication was established by means of large pipes. When a boat is enclosed in the first chamber, and the gates of it are closed, the communication between the two chambers is opened, and the water, instead of being lost in the lower reach, goes partly to fill the second chamber, until the same level is established in both. The lock gate is then opened, and the boat goes out. The second lock is then partly filled, in such a manner that at the next lockage it requires, to be brought to the highest level, a much less quantity of water. The second lock is then emptied in the same manner as the first.

This system has been applied to the locks of Aubois. M. de Caligny has altered in various manners the application of this principle; he places the two chambers in communication in different ways; he employs also auxiliary basins, called *bassins d'epargne,* in order to diminish the loss of

water. These basins are arranged to receive the largest possible height of water every time the lock is emptied. The larger these basins are, the greater is the saving. The various local and economical considerations must decide the space given to these basins. But theoretically, each time the water is drawn from the lock it ought to be collected in a basin at a slightly lower level, and should be restored to the lock with very little loss.

This system of lockage has recently drawn the attention of several engineers, on account of the simplicity of its operation and the small amount of loss involved.

THE FUSION OF PLATINUM.

M. H. Violette, director of the saltpetre refineries of Lille, has presented to the Academy of Sciences a note on the fusion of platinum in a small ordinary furnace; this furnace, which was about 1 metre cube, was placed in communication with a chimney 98 ft. 6 in. high, and 3 ft. 11 in. in diameter, connected with eight large furnaces, surmounted by boilers, and maintaining a constant and energetic draught. The combustion obtained in the experimental furnace was very active, and the draught violent. Crucibles of various materials containing pieces of iron were submitted to the heat of this furnace, and were rapidly fused with their contents. M. Violette obtained the best results with a Hesse crucible, which was subjected to a partial fusion, although the carbon lining resisted perfectly. In a crucible of this class he placed 50 grammes of platinum, partly spongy and partly in fragments, and after an hour he withdrew from the crucible a button of platinum, weighing 50 grammes, and perfectly melted. M. Violette was also able to repeat in his trial furnace the experiment of obtaining crystallized aluminium by heating together a mixture of aluminium and borax. There is considerable interest attached to this latter experiment, as many precious stones, the sapphire, the opal, the ruby, the emerald, the topaz, etc., are only colored alumina.

THE SUEZ CANAL COMPANY.

On the 26th October was decided before the Tribunal of Commerce of the Seine, the process brought by the Company of the Messageries Maritime against the Suez Canal Company. We give below an abstract of the leading features of the judgment. "It being found on examination of the tariff of the 4th March, 1872, that it has for its object the sensible modification, to the prejudice of ships passing through the canal, of one of the essential elements of the toll charged, and consequently of the tax itself. That in effect this tariff involved that in the future the navigation duty of 10 francs per ton will be levied on the real capacity of ships, instead of being charged on the legal capacity determined by the number of gauged tons, calculated upon the law established, and the customs existing in France at the date when the concession was signed; that it involves also that the charge will be made on the gross tonnage established according to the English system, substituting for the previous base of calculation an entirely new one. It is decided that there is no good ground, and that it is without justice, that the Suez Canal Company, by its deliberations, dated 4th March, 1872, has declared its intention of modifying the tax levied by special right on ships passing through the canal."

MAN ENGINES.

For the purpose of lifting the miners out of deep mines without the use of rope and kibble, man engines were invented forty years ago by Bergmaster Dörrell, of Clausthal, in the Upper Harz, when he used two pump rods, which, side by side, went up and down a shaft, and fixed to them small platforms and handles at all those points of the rods which came opposite after every stroke. So, by simply changing his stand after each stroke from one rod to the other, a man would be lifted up to the surface without any exertion. This ingenious system was soon imitated in other parts of Germany, Belgium, France, and England, and generally special machinery was designed to drive these man engines. At the deep silver-lead mines of Przibram, in Bohemia, since 1854, in the Maria shaft, a direct-acting man engine, with 2 steam cylinders and cataract reversing gear, has been employed, both rods being connected by chains, which run over pulleys; the great wear and tear of the latter, however, the great pressure of steam required, the inequality of the engine's stroke when differently loaded, and other inconveniences, caused this direct-acting engine to be abandoned and replaced by another indirect-acting man engine in the Anna shaft. This latter was constructed so as to transmit the up and down motion

from a rotating crank by two pump crosses —by the by, exactly the same principle which was originally employed by the inventor. This system is now quite successful at Przibram, and a small condensing steam engine, working expansively, is quite sufficient to work it with the greatest safety and regularity, a brake attached to the fly-wheel controlling the engine with certainty, whenever required. The engine reaches a depth of 400 fathoms, and 3,000 men go up and down it daily, in about 9 hours (3 hours for each shift); it makes 4 to 5 strokes per minute of 10 ft. each, requires 6.2 to 6.9 lbs. of coal per hour, and per effective horse power, and costs from 2s. to 2s. 3d. per horse power in 24 hours. Quite recently the old engine in the Maria shaft has been also replaced by a similar one, only the stroke of the rods has been increased to 12 ft.

ROTARY PUMPING ENGINE.

A large pumping engine has been more than three years at work at the lead mines of Bleiberg, near Aachen, in Rhenish Prussia, and as its economical results are highly satisfactory, it begins to be imitated in other mining districts. It is a Woolf compound engine, and was constructed at Seraing by M. Kraft, of that famous establishment. The peculiarity of this engine is that the steam cylinders do not act directly upon the pumps, but through a crank shaft with fly-wheel upon a balanced beam, to which the pump rod is attached in a parallelogram. The large cylinder has 2.5 metres stroke, and 2.0 metres diameter; the small cylinder 1.25 metres stroke and 1.6 metres diameter; the air pump 1.02 metres diameter, and the same stroke as the small cylinder. The steam is cut off in the small cylinder at 7-10ths of the stroke. The pump rod is constructed for the lift, and counterbalanced by weights fixed to the opposite end of the beam; it drives four sets of pumps of 182 metres length, and 0.65 metres diameter, besides a suction pump, of 60 metres length, 0.82 metres diameter, and 3.125 metres stroke, upon the bottom of the shaft. The proportion of stroke of suction pump and forcing pump is 5 to 4, the weight of water column of all five sets, 100 tons, being equal to a load of 21.75 lbs. per square inch in the large cylinder. The engine is provided with eight Cornish boilers, with two flues each. The boilers are 8.5 metres long, 2.0 metres wide, and each boiling tube is of 0.75 metres diameter. The boilers work with 60 lbs. pressure, and the engine makes on an average 3¼ strokes per minute, though it has been worked with ease 8⅓ strokes, but with ten strokes the pump rod attained so much vibration that it was expected to break. The economy of coal is most remarkable with this engine, as it only requires 1.75 kilogrammes, or 3.85 lbs. (English) per hour, and per effective horse power.

MINERAL TREASURES IN BOHEMIA.

Austria, though one of the Continental countries which are richest in iron ore, is still obliged to look for her supply of iron, particularly rails and large rolled bars, to foreign markets, and even the fine structures of the forthcoming Vienna International Exhibition are made from foreign iron. This anomaly is simply caused by the great want of good mineral fuel in those districts which are richest in first rate iron ores, such as Styria and Carinthia, while Bohemia and Moravia own very considerable coal-fields. One of the most considerable deposits is the coal basin of Kladno, Schlan, and Rakonitz, north-west of Prague, with an area of more than 650 square miles, of which, up to now, hardly one-fiftieth part has been opened, owing to the want of railway communication and industrial spirit. Near Kladno, a coal seam, which rivals the 10-yard coal of Dudley, has been opened at several large collieries, with a thickness of 36 ft., and traced for over 1,000 fathoms in its dip; this seam alone produces over 1,000,000 tons annually. It is further traced over a distance of 15 miles by many pits, and not long ago it was discovered again at Rakonitz, 16 ft. thick at 80 fathoms depth. Its dip is with great regularity towards north, where its existence may be supposed as almost certain below the Permian and Cretacean rocks. Besides the main vein, some minor seams, which are interposed to the Permian strata, belong to this coal basin, and they are worked with profit in many mines far beyond Schlan, so that a workable thickness of at least 45 ft. of coal may be taken for granted; and the quantity of coal in this basin is estimated at about 16,000,000,000 of tons. The cost of raising the coal at the pits of Kladno, from a depth of about 200 fathoms, is estimated at from 4s. 9d. to 5s. 7d. per ton, while the price is about 10s. to 11s. at the pit. The coal is a very good fuel for all heating purposes, as

well as for the manufacture of iron, although the coke which it makes is not exactly of the best kind, as the coal contains much sulphur, and the coke is rather brittle.

NEW BUILDINGS AT PARIS.

According to an official report published by the Prefect of the Seine, it appears that the number of new buildings in Paris during 1871 amounted to 4,230, whilst the number of houses pulled down to make room for improvements was 1,418. In the suburbs the number of new houses built greatly exceeds that of those demolished.

A SOLVENT FOR SHELLAC.

Dr. I. Walz describes the following process for obtaining a neutral solution of shellac in water. The shellac is broken up and covered with a concentrated solution of carbonate of ammonia, and boiled upon the water-bath until the ammoniacal smell has disappeared. More of the solution is added, and the boiling is continued until the shellac forms a coherent sponge-like mass. The carbonate of ammonia is then expelled by further boiling, and the mass will readily dissolve by pouring boiling water upon it. A kind of soap will be found floating on the surface, which may readily be removed by straining. The solution, brought on paper, cloth, etc., dries rapidly, and leaves a thin, lustrous, and adherent film of shellac behind.

THE UTILIZATION OF PEAT IN ITALY.

A company has just been formed in Italy for working some of the numerous peat deposits in that country. A machine recently patented by Signor Moro is to be used for compressing the peat, and is stated to have given excellent results at some trials recently made at Florence; and the fuel manufactured on this system has been used extensively by the Alta Italia Railway Company; and, as compared with English coal, a saving of 40 per cent. in expense is effected. The high price of coal in England will doubless offer an opportunity to utilize the abundant deposits, not only of fuel, but lignite, and other fossil fuel, which are met with in many places in Italy.

JUTE.

The jute plant grows with a tall, coarse stalk, in the best Indian fields seldom above 15 ft. high, and perhaps three-quarters of an inch in diameter. Some varieties are branchless, the leaves being set upon long foot-stalks, while others put out limbs somewhat abundantly. It has a small yellow flower, and some varieties yield their seed in a long pod, while in others the seed vessel is a small ball or button. The seed is of but little or no value, yielding too little oil to make it worth while to crush, and it is not very nutritious for stock. Moreover, the amount is small, as if all the stalks were allowed to ripen their seed, they would produce scarcely more than 125 lbs. to the acre. More use is made of the stalk, which, like long willow stems, are made into baskets, or plaited into various kinds of wicker-work, or burnt into fine charcoal for certain special purposes, as the manufacture of gunpowder, or for druggists' use. But the chief value of the crop is for the fibre which surrounds the stem, like the fibre of the flax or the hemp plant. This, as is well known, is used for most of the coarser kinds of woven fabric, such as sacking, bagging, mats, etc. Some portion of the better fibre is also mixed with cotton and wool, as in part a substitute for these more expensive materials. Some time ago, certain kinds of shawls were imported into this country at prices considerably lower than it was understood they could be made for at home. The difference was so great as to cause much surprise, when closer examination revealed the fact that no inconsiderable proportion of jute had been woven in with the wool. Coarse as the material usually seems, a certain part of the fibre of some varieties of jute is so soft and silky as even to be used to adulterate silk, and in this form also it appears in our market. The temptation to such uses is readily seen when it is remembered that jute is the cheapest of all fibres. It is said that it can be produced in India for one-fifth, or even one-eighth, the cost of cotton; and perhaps there is no reason why the relative cost of production should not be very nearly the same in this country.

BAMBOO PAPER.

The Consul-General at the Havana has recently called attention to the enormous quantities of fibrous vegetables which the island of Cuba produces. Some paper-makers have made experiments, it is said with success, on the fibre of the bamboo, and on some of the creeping plants indigenous to the island. The

bamboo has been devoted to the service of literature as long as the papyrus itself. More than 2,000 years before the Christian era, the conquerors of China signalized the establishment of a new dynasty in the Flowery Land by a conflagration of the national records. These documents were written on plates of bamboo. How far they went back takes us almost beyond the Flood! The dynasties of Yu, Chang, and Chea had inscribed their records on bamboo plates for a thousand years before their barbarous destruction under the reign of the Thsin kings. Books of this primitive nature may be seen among the curiosities in the King's Library at the British Museum. But to use the plant, not as wood, but as paper, to tear asunder the durable and jagged fibres only that they may be felted together in a finer and closer union—to supersede the toil of the *chiffonnier* by that of the cane-cutter—is a new application of an old material. It would be of great utility to those who are making experiments of this nature on the utilization of the vegetable fibre, to make themselves acquainted with the mode and materials of manufacture now used in Japan. Paper, in that wonderful island empire, serves purposes unknown in literary Europe. It is hard as *papier maché*, or soft and delicate as cambric. It is there used for manufactures as diversified as they are numerous.

NOTE ON HEATING STEAM.

By LE CHATELIER.

Translated from "Les Annales du Conservatoire."

The object of the experiments herein recounted was to control directly the effects produced by injection in the cylinders of a locomotive during reverse stroke.

Every-day experience shows that by drawing from the boiler a small stream of hot water which vaporizes only 13 @ 14 per cent. because of the decrease of pressure—we prevent the return of the gases of combustion into the cylinders during the reverse.

The quantity of water thus expended, in proportion to the loss of vapor and leaving the chimney, is equal to the quantity of steam expended; if the object is only to fill the cylinders in order to prevent the entry of gas and its return to the boilers.

The water mixed with $\frac{1}{7}$ to $\frac{1}{8}$ steam, which passes under the slide valves and through the ports into the interior of the cylinders, is reduced to vapor by the contact of the heated metallic surfaces.

The conditions are the same as those occurring when a saturated vapor exchanges its latent heat with a liquid which vaporizes at lower pressure and temperature.

Experiments cited by M. Peclet in the second volume of his "Traité de la Chaleur," show that when the liquid is heated in a worm in which the steam is subjected to rapid motion and the liquid is boiling, vaporization increases to 8 or 9 kilograms, or to a mean of 8.5 kilograms to the square metre per hour in proportion to the difference of temperature. Under a steam pressure of 7 kilog. @ 7.5 kilog. per square centimetre, and under atmospheric pressure, *i. e.*, for a difference of about 70 deg., there is a generation of steam amounting in round numbers to 600 kilog. an hour to the square metre; while the boiler of a stationary engine, heated by radiation from the furnace and contact with the heated gases, converts into steam only 20 @ 25 kilog.; and a locomotive, 35 to 40 kilog.

We have thought it would be interesting to make a direct experiment by setting water in very rapid motion within a worm and applying outside saturated steam under pressure.

In a closed vessel tested for 12 atmospheres, we set a copper worm 2½ millim. thick, 5 centim. in interior diameter, and 8.30 metres long, having a surface of 130 square metres. At one end was attached the injecting pipe of a locomotive engine; at the other end was affixed a glass tube of equal diameter, through which the steam escaped into the atmosphere. This could also be connected with the boiler.

The influx of water and steam was regulated by varying the delivery of the injection stopcock. This was done either without sending the steam from the boiler through the worm, or by putting the vessel in free communication with the boiler.

The delivery of the stopcock at different openings was determined by six series of experiments: three by gauging the lowering of the water in the boiler, and three by careful measurement of the product of condensation. The effective pressure varied from 7 to 7½ kilog. per square centimetre.

The result of gauging is contained in the following table:

Opening.	Delivery in Kilog. per min.	Kilog.
3 tons 1/4	1/6 (25 + 25 + 24.7 + 25 + 24)	= 24.8
2 " 3/4	1/6 (20 + 21 + 22 + 20.2 + 20 + 21.5)	= 20.8
2 " 1/4	1/6 (18 + 17 + 19 + 19 + 18 + 19)	= 18.3
1 " 3/4	1/6 (15 + 13 + 12 + 14 + 15 + 13)	= 13.7
1 " 1/4	1/6 (12.5 + 12 + 10 + 10.5 + 10 + 11)	= 11.0

When the worm is not surrounded with steam, little vapor and much water are discharged. With a delivery of about 25 kilog. per minute, the water is projected with considerable force in a trumpet form, the centre being filled with steam. The interior of the glass tube is opaque, and water is seen running along its sides. When the injection diminishes, the water separates and runs along the lower edge of the tube, when it is reduced to 10 @ 15 kilog., the water collects in the worm, and the discharge is intermittent.

But as soon as steam at 7 or 7.25 kilog. is admitted about the worm the aspect of the *jet-d-eau* changes entirely. When the delivery is about 25 kilog. per minute, the jet receives a considerable velocity, the steam is white, flaky, and moist to the touch; but the eye cannot discern liquid water, while the glass tube is filled with opaque vapor.

At $2\frac{3}{4}$, with a delivery of about 21 kilog. per minute, the vapor discharged is only a little white and flaky at the end of the tube; within it is slightly opaque, and veins of vapor are observable, charged with water and beginning to become transparent.

At a little more than 18 kilog. delivery per minute, only a small quantity of water is to be seen; the pencil of white vapor shows at a distance from the orifice, connected to it by only a few white veins, and the divisions on a manometer, 60 @ 80 certain, behind the tube, can be read.

At about 14 kilog. per minute delivery and below, the vapor is absolutely dry and transparent as air, both in the tube and at some distance from the orifice.

At a pressure of 7 @ 7.25 kilog. to the square metre at a temperature of 170 deg. in the vessel containing the worm, we may suppose that the water is completely vaporized when the delivery is reduced to 16 or 17 kilog. a minute. Below this the steam should be a little superheated.

These numbers, with reference to the quantity of water taken from the boiler, correspond to a production of steam of 740 @ 780 kilog. per square metre, per hour; the difference of temperature being 70 deg., *i. e.*, about 10 to 11 kilog. to a degree of temperature.

Subtracting 13 per cent. for the steam formed at the moment when the water leaving the boiler suffers a reduction of pressure and a partial vaporization, the above figures reduce to 9 and 9.7 kilog., a result differing but little from that obtained by Peclet.

The time during which the water remains in the worm may be calculated approximately by supposing that $\frac{1.3}{100}$ of vapor and $\frac{8.7}{100}$ of water enter the tube, and by taking the mean of the calculated velocities of influx and efflux. For a delivery of 16.50 kilog. per minute, or of 275 grammes per second, we have

Velocity of influx	30 metres.
" efflux	230 "
Mean	130 "

The length of the worm being 8.30 metres, the vaporized water passes through at the rate of $\frac{8.30}{130} = 0.0638$, or about 6 centièmes per second.

In a locomotive engine, for example, in the case of 8 coupled wheels, generally with a single cylinder, the totality of metallic surfaces which have contact with the water of suspension in the steam, and which assist in its vaporization, may be estimated as follows:

Interior of the escape port	0.1275	sq. met.
Lateral surface of escape port	0.1312	"
Admission port	0.2450	"
Cylinder basis	0.3926	"
Faces of piston	0.3926	"
Cylinder surface	1.0366	"
Escape port	0.1232	"
Total	2.4487	"
For two cylinders	4.8974	"

or about 5 square metres.

This entire surface cannot be regarded as

a permanent surface of vaporization; $\frac{60}{100}$ or about 3 square metres may be taken as the minimum that permanently acts in vaporization. It is difficult to estimate the difference of temperature of the metal when heated by condensation of steam and cooled by water. During the period of return to the boiler, there is in the cylinder an excess of pressure 1 @ 2 atmospheres over that in the boiler, and the steam rises in it to a temperature of from 5 to 10 deg. higher. The metal instantly heats, but a part of this heat passes into the interior of the mass; the opposite effect occurs during vaporization. We have not, then, as in the case of the worm in the experiment, a transmission through a small tube under a constant temperature of 70 deg. But, with exception of the slide valves, the effects occur at the surface without interposition of an envelope, which, though conductive, hinders the transmission of heat. Besides, the duration of contact is greater. Suppose a locomotive going at the rate of 29 to 30 kilom. per hour with wheels of 1.30 m. diameter. The number of revolutions per second is 2. The period of vaporization, assuming it equal to that of a semi-revolution, is 0.25 seconds; *i. e.*, four times as long as the time of passage of water in the worm.

The vaporization in the worm represents 12.70 kilog. per square metre each minute. Applying this co-efficient to the cylinders, for 3 square metres of permanent vaporization, we obtain 38.1 kilog.

Neglecting the hypothesis that the longer period of time for the water in the cylinders, and the absence of an interposed envelope, compensate for the causes that diminish vaporization, we may infer that there may be a condensation of water amounting to from 10 to 20 kilog. per minute.

The conditions in the experiments with the apparatus and in the case of the locomotive, are not identical, but they are of the same nature; and the results are in the nature of a demonstration, hardly necessary in view of the facts of every-day experience.

CONTINUOUS EXPANSION ENGINES.

From "The English Mechanic."

At a recent meeting of the London Association of Foremen Engineers a paper was read by Mr. Nicholson, on "Continuous Expansion Engines," which give rise to an animated discussion. We give below an abstract of the paper and some of the salient points in the discussion. Mr. Nicholson commenced by saying that although compound engines were now the order of the day, great diversity of opinion existed as to which was the best style of compound engine. He had been an advocate for economizing steam power for upwards of 30 years, and 20 years ago had asserted that until engineers became shipowners, and shipowners became engineers, they would continue to blow their profits out of the funnel. Mr. Nicholson thinks there is reason to hope that great improvement will yet take place in the steam-engine, and as a contribution towards perfecting it he sketched an ideal perfect engine. "If," said he, "we could make an engine and cause the piston to recede and advance to fit a conical cylinder perfectly in all parts of its stroke, we should have a uniformity of motion. It is quite practicable to bore the cylinders out conically, yet it seems to me a difficult matter to make the piston fill the cylinder in all parts of the stroke. If we could do that the steam when expanding would decrease in pressure in proportion as the piston increased in area; therefore the weight on the piston would be nearly uniform in every part of its stroke. If that could be accomplished double cylinder expansion would soon be at an end. The great secret of expanding steam to the best beneficial results is uniformity of motion. If single expansion could produce a steady motion, it would give us all that we wanted in expanding steam. It is not natural for it to do so; therefore it is necessary to resort to other means for a remedy.

"I wish by this rough sketch to convey to your minds my views of perfection. This is a theoretical or an imaginary engine. I cannot see how it is possible that it can be practically made, but nevertheless we can make a practical engine in close approximation to this imaginary engine. I am of opinion that those who can make substantial commercial engines will find that the nearest approximation to this imaginary engine will be the nearest perfection in practice. Single-cylinder expansion engines

have had to give way to compound engines. I mean two cylinders, each expanding their own steam. This imaginary engine, as I have named it, is also a single-cylinder expanding engine, but of a very different type to any other engine that ever expanded steam. The Woolf's engine is now doing a marvellous duty, and it is hard to conceive how it could be so long kept in the background. It is now saving this country hundreds of thousands of pounds sterling annually. It is a pity that Woolf could not live to see his ideas more generally adopted. When he was working at Meux's brewery in London, he perhaps did not anticipate the extraordinary benefits that have arisen from his views of working steam; yet, gentlemen, although Woolf's engine is adopted by all compound engine builders, it is far from perfection. In my opinion it can scarcely be called an expansion engine; it amounts to a high and low pressure engine working in unison. The mean pressure on the low pressure engine is the mean resistance on the high pressure engine, therefore the work done is minus the area of the small piston at the mean pressure of the large piston, or, in other words, the area of the small piston should be deducted from that of the large piston. Woolf's engine is now the order of the day; but how long it will continue to be so would be hazardous to say. The only engine on the compound principle that is in the market at present as a competitor to Woolf is the continuous expansion engine made by Mr. John Stewart, Blackwall Iron Works. The steam in that class of engine is worked in a different channel from any other engines. It is cut off at about half stroke on the small piston. At the time the small piston passes the cellular ports in the sides of the small cylinder, the two pistons begin to share the steam between them. At the same time they begin to expand the steam when the small piston has finished its up or down stroke. The large piston continues to expand the steam until nearly at the end of its stroke, which causes it to be as its name denotes, viz., a continuous expansion engine. The steam is a less time exposed to the atmosphere than in the ordinary compound engine; it gives out a steady motion, and each cylinder can be worked separately at pleasure, which is a great consideration in case of break-down. Mr. Stewart is now busy with the tenth boat on the continuous expansion principle. The engines of this boat have to be converted from ordinary condensing engines into continuous expansion engines. The ship belongs to Egypt, and has 140 nominal horse-power.

"Many of our large firms went very reluctantly into making compound engines. It has only been the pressure of the shipping interest that has caused this change, and many, even now, are very sceptical on the advantages effected by the change. I have a notion that the three-cylinder engines will prove the most economical ones in the end. They will give a better motion when properly constructed, and the sub-division of power will be a great advantage to makers. The cylinders will be much smaller in proportion; there will be less risk to run in manufacturing, and very much less risk to run when at sea; more particularly so when constructed on the continuous expansion principle, working in unison with Woolf's engine. The engines can be worked separately at a moment's notice, and the two principles can be worked separately at pleasure; that is to say, one can be disconnected from the other in any case of necessity, and it would be difficult to point out a case where you could not make headway at sea, without all three cylinders were breaking at one time (as each could be worked separately), and such an accident as that would be unprecedented; under these circumstances, you would be safer at sea, than under the ordinary compound engines. The whole of the useful effect would be taken out of the steam, and the power of the engines augmented whenever required. Another important feature in this class of engines is that you could have a greater range of expansion than in the ordinary compound engines, and the full pressure of steam from the boiler might be put on to all of the pistons with impunity at any time. The best results may be got from these engines, without superheaters, water-warmers, or cylinder-jackets. Superheaters soon destroy themselves, water-warmers are a superfluity, and cylinder-jacketing involves great risk and expense in moulding. When water can be put into the boilder at 120 deg., there is not much need for water-warming if the condenser answers all the purposes necessary. Nothing is unnecessary where safety is the greatest object. As far as economy is concerned, there has been many an application which has turned out a mistaken notion. I think steam simply and purely from the boiler can be acted upon to

suit all purposes necessary for the well working of marine engines; if there are parts that can be dispensed with, it ought to be done in sea-going engines, as they get neglected, and are difficult of repair in foreign parts, far from home; and instead of being beneficial they turn out disadvantageous to engineers and shipowners.

"The continuous expansion engine is applicable to all purposes, and more particularly where a steady motion is required, such as flour or cotton mills; and the full range of expansion can be got, irrespective of size of cylinders. They are nearly as economical when working non-condensing—commonly called high pressure—as the ordinary condensing engines, and are also well adapted for American rivers. The steam could always be worked to within 1 lb. of the atmosphere, and no more noise would be heard than from a condensing engine; by reducing the steam to atmospheric pressure the engines would be struck dumb, no air or vapor pumps working; the friction would be reduced to a minimum, the engines would be easier to keep in repair, and much cheaper at the first cost than condensing engines. This class of engines has been tried on railways; 2,000 miles have been run on the Great Eastern, and 5,000 miles on the Brighton and South Coast Line with express trains. Some may be thinking of asking me why that class of engines was not adopted. The one was compounded at Stratford in the year 1850, and the other at Brighton in the year 1851. The year of the first Great Exhibition, I might venture to say that there was not a Director on either of those lines who knew a word about it. I was never spoken to by one of them; the engines never broke a bolt, nor were ever one moment behind time; the engines were dismantled and put back to their ordinary style of working without any record of the duty performed by them. They were not the most intelligent superintendents on the lines mentioned, at the time of the experiments.

"It is time that this class of engines should be more generally known. Let them stand on their own merits or fall by their demerits; if there be anything good in them, let us understand it; if there by anything bad, let us understand it also. Our scientific journals cannot agree; they have come to no decision on the point after many months of a paper war. One journal says as much as that it was my father's custom, and it ever shall be mine; the other is more progressive, and says that compound engines are most economical, and give out the best motion.

"There are also other important points of economy besides the consumption of fuel. Iron is a very dear article; and to preserve the boiler—that is, to make it last longer—is of very great importance. I am of opinion that water might be regenerated so as to work more harmoniously with the iron that composes the boiler. Water worked over and over again loses a something that I cannot define. I am not chemist enough to give a decision; it seems to me something like breathing our own air over and over again, until it poisons us at last; the water being robbed of some of its natural compounds, seizes the boiler to make up the deficiency. If the feed water were allowed to mix freely with the atmosphere previous to entering the boiler, it would obviate some of the consequences that often take place. After the water has been mixed with the atmosphere it could easily be re-heated and pumped into the boiler in a purer state; it would also add to the durability of the boiler.

"The difference between the continuous expansion and ordinary compound engines is, that in the ordinary compound the steam has to expand in the first cylinder until nearly the end of the stroke; then the steam passes to the second cylinder. If cut off at half stroke, the steam would then be half of the boiler pressure, before it entered into the apertures prepared to receive the steam previous to acting on the second piston. In the continuous expansion engine the steam goes through a different channel. As soon as the piston passes the cellular ports in the side of the first cylinder the two pistons share the steam between them; therefore it is absolutely necessary to proportion the engine with minimum ports, not to throttle the engine in order to get the maximum power. That is the reason why the hollow valve or travelling steam chest is introduced between the two cylinders, to receive the steam from the first cylinder and pass it to the second cylinder. The steam does not enter into the steam chest; it passes through the hollow valve, which is nothing more than the continuing of the steam ports from the one cylinder to the other. Both pistons are running in the same direction, and the pressure of the steam on the large piston is just in proportion to the

space that it is filled; the smaller the spaces the greater the pressure, that is, minimum spaces and maximum power. As steam expands, its pressure is in an inverse ratio to the space that it has filled. Steam ought to kill itself by its own energy; it ought to work itself to death, and not to waste its energy in filling spaces that are useless. Unfortunately for Woolf's system of working, the greater the pressure on the large piston the greater the resistance on the small piston. Not so in the continuous expansion engine. Instead of a resistance there is a great assistance by a vacuum being formed in the first cylinder as well as the second. Very long-stroked engines, working from 12 to 14 strokes per minute, would not give such good results by being connected to the condenser; but engines running from 60 to 100 strokes do not allow time enough for the cooling to take place in the cylinder, therefore the continuous expansion engine will give out considerably more power with the same area than any other compound engine yet discovered."

The Chairman (Mr. Gibbon) thought there could be no doubt as to the imperative necessity of saving fuel in the production of steam, wherever and whenever that could be done. He remembered one of the steamers on the Thames, which, twenty years ago, was reckoned to be one of the fastest on the river. How many boats had been built since, how many improvements had been proposed and carried out, he could not tell; but how much could be said in praise of them in the face of the fact that the steamer he alluded to still remained the victor in speed over all those constructed during such a period of years?

Mr. Thorburn said he might be wrong in his conjecture, but if, as he understood, the steam was only carried through one half of the stroke, there must be a very high initial pressure, or the actual working pressure would be lost. Another thing was, that the opening in the centre of the cylinder would appear to be detrimental to the packing of the piston.

Mr. Nicholson, in reply, said, as to the durability of the steam cylinder and cellular ports, there could be no doubt about the supposed detriment being rather an advantage. A practical illustration of the effect was established in six stationary engines which had been established in London 15 years ago. In reference to the pressure of steam and the transmission of it from one cylinder to another, he stated that when the steam was let in from the boiler that could be done in the twinkling of an eye. As an instance of the saving in fuel, he would cite the case of a boat called the Southampton, the engines of which had been converted. Whereas this boat formerly used 14½ tons of coal in the 24 hours, she now used about half that amount; and besides that she greatly increased in speed. If half the thought and talent bestowed on the Woolf engine were devoted to this new principle, it would be better for the trade of the country. As to the value of the old engines, he was far from deprecating what good they might effect, but it would be the height of absurdity to apply the principle of the Cornish engine to a steamboat. Whatever its merits might be regarding stationary service, in a steamboat it would have the effect of a punching engine; it would tear the ship from stem to stern. In the expansion engine, as well as in the Woolf, the steam can be worked at any part of the stroke, and more than that, the full range can be obtained irrespective of the size of the cylinders in the continuous expansion engine.

By the end of the present season the Chicago and Alton Railroad Company will have one-fourth of its road laid with steel, and it has contracted for enough to lay another quarter of the road by the end of the next season. On this road is now running one of the most complete trains in the world. It consists of a baggage and mail-car, four coaches, and a palace dining-car. It is equipped with Thornton's spark-arrester and patent dust-shield, Goodale's steam-brake, Creamer's safety-brake, Blackstone's patent platform and coupler, and Reniff & Buttolph's ventilators. The managers announce that the whole road will shortly be equipped in the same way.

English experience, during the past 20 years, proves nothing more conclusively than the absolute feasibility of consuming smoke in the furnace of locomotives. More than 200 trains per day pass the Kings Cross station of the London Underground Railway, and yet no one has ever been heard to complain of smoke in the tunnel.

PETROLEUM.

(*Continued from page 520, Vol. VII.*)

V.

REFINING.

It is perhaps safe to say, that among the great majority of people who use refined petroleum, and even among those to whom the question of fire-test is a matter of interest, the impression prevails that it is a simple fluid like water, which by sufficient heat is resolved into a single gas or vapor; a want of comprehension of this point is the foundation of all the misunderstanding that exists upon the value of fire-tests and the safety and properties of the article used.

For instance, it was gravely decided a short time since in an Ohio court, in the case of a man who was prosecuted for selling a burning fluid composed principally of benzine, that there was no infraction of the statute because the article sold was not an *oil*.

Now the cause of this lies primarily in the fact that rarely, if ever, do two samples of petroleum give precisely the same results on analysis, and also because different investigators have given separate names to the different series of hydrocarbons evolved.

All petroleum, however, consists of a great number of distinct hydrocarbons, included in the first or paraffine series, the second or olefine series, and the fifth or aromatic series. The natural crude, although varying greatly in different localities, may be divided as shown in the following table:

1st Series—Paraffines.

Name.	Formula.	Specific Gravity.
Methane	CH4	.....
Ethane	C2 H6	.....
Propane	C3 H8	.....
Quartane	C4 H10	0.60 at 32° Fahr.
Quintane	C5 H12	0 628 " 63° "
Sextane	C6 H14	0.669 " 61° "
Septane	C7 H16	0.699 " 59° "
Octane	C8 H18	0.726 " 59° "
Nonane	C9 H20	0.741 " 59° "
Decane	C10 H22	0.757 " 59° "
Undecane	C11 H24	0.765 " 61° "
Duodecane	C12 H26	0.776 " 68° "
Tridecane	C13 H28	0.792 " 68° "
Quatuordecane	C14 H30	.....
Quindecane	C15 H32	.....

Some of the heavier crudes contain, doubtless, paraffines of a still higher order and of the lighter crudes, the ethane and propane are given off as gas as they issue from the ground.

2d Series—Olefines.

Ethene	C2 H4.
Propene	C3 H6.
Quartene	C4 H8.
Quintene	C5 H10.
Sextene	C6 H12.
Septene	C7 H14.
Octene	C8 H16.
Nonene	C9 H18.
Decene	C10 H20.
Sexdecene	C11 H22.
Septivigintene	C27 H54.
Trigintene	C30 H60.

5th Series—Aromatic Hydro-Carbons

Benzine	C6 H6.
Toluene	C7 H8.
Xylene	C8 H10.
Cumene	C9 H12.
Cymene	C10 H14.
Amylxylene	C13 H20.

This last series might be regarded as derived from the corresponding paraffines by the abstraction of 8 atoms of hydrogen.

We have here already a list of 33 separate and known hydrocarbons, all of which are found in the several varieties of American petroleums, and which are separated from each other merely by different degrees of heat; many others yet unknown doubtless exist to which no special individuality has yet been given.

A thoughtful consideration of these facts will make apparent how very foggy on this subject must have been the minds of the legislators whose enactment was baffled in the Ohio court.

The subdivisions given are taken from Fowne's Chemistry, and they have not been touched upon here any further than necessary to illustrate the point above made; while by no means novel, they have not heretofore been presented in such a way as to impress very forcibly those who have not the time or inclination for a close study of the subject.

The refined oil of commerce has been freed from both the lighter and heavier members of each series, and should consist of the paraffines ranging between C6H14 and C13H28; of the Olefines between C6H12 and $C_{11}H_{22}$, and the last two or three members of the aromatic series; such, however, is the peculiar nature of the lighter

vapors that they never can be totally expelled even from oil which is supposed to have a fire-test of 120°—150°, but seem to blend and cling as it were to some extent to the heavier paraffines.

Age is, perhaps, the only sure method of expelling these lighter members; for this reason, an oil composed principally of the heavier paraffines may contain some small quantity of these light members that will flash in an ordinary fire-test, while an oil composed almost entirely of the intermediate or mean members of the series will not flash at a much higher temperature, although actually by no means as safe or as profitable to burn.

The different crudes from various sections of the Pennsylvania region vary considerably in their composition; the lower creek and Parker's landing produce a light green oil of 47 deg. gravity; Shamburg and immediate vicinity, a light green oil of 46 deg.; Pleasantville, a black oil as it is called (really but a darker green), of 47 deg.; Hickory, a black oil of 47 deg. – 48 deg.; Church Run, near Titusville, a light green oil of 46 deg., which is more desired by refiners than any other crude in the region, giving a better percentage of refined from the absence of the lighter paraffines.

The black oil, for the opposite reason, is held at some discount, giving more tar in distillation, although it is not of sufficient moment to cause separate tankage, the oils being thrown together and mixed in the pipe-line tanks.

The proportion of methane or marsh gas which is thrown off from the oil as it reaches the surface, is greatest in the wells of the lower region.

In the construction and arrangement of refining, we have in the main, after many trials, returned to original principles in process and apparatus, although with greatly superior workmanship and larger capacity; among the improvements which seem to have survived actual test, may be mentioned the spray condenser, the use of steam in the stills, and the increase in the size of the still itself.

Of the spray condenser it will be observed that it was intended to do away with the vast amount of pipe required in the old worm, and that it consists of an exterior cylinder into which the vapor is passed and subjected to the spray from a finely perforated interior cylinder which is filled with cold water under pressure, the uncondensed vapor from this treatment being then subjected to the action of steam.

The objections to it are, that it takes ten times the quantity of water required by the old worm and that it is not thorough in its action, that steam and vapor will escape from the tail-pipes and cause waste, and that the expense when completely fitted up is not much below the cost of the necessary worm.

In the use of steam in the still the pipe is introduced at the bottom in the centre of the still, carried up to within six inches of the top with four or five horizontal branches. The heat of the oil in the still superheats the steam, and its action is to blend with and carry off the vapors more rapidly through the pipes than they would move of themselves, and to place them in the condenser in a heavier state than could be accomplished by their own buoyancy alone. Steam is not turned on in the still until the lightest vapors have been run off, and fires are often drawn in the last hour or two of the running and the balance run off by superheated steam alone.

The advantages of large stills (from 600 to 2,000 bbls.) are so obvious in saving of labor and fuel, that it will be only necessary to enumerate the disadvantages, which are thought by some to overbalance the claim for adoption.

They are thought to be less manageable and more dangerous; if from any cause a leak breaks into the fire, there is little or no chance of control; with a small still the leak could burn without serious loss.

If repairs are necessary the whole capacity of the still must, of course, be idle.

Also a 600 bbl. still can be run twice a week, making 1,200 bbls.; four 150 bbl. stills can be run four times a week, making 2,400 bbls.

When we add to the three improvements above specified the agitation of the oil in its acid and alkali treatment with air from an air-pump instead of the old fashioned paddles, we have probably summed up all the changes of importance, not including, however, the various special processes for making particular brands of machinery and burning oils.

While the lighter oils are generally cut off (as it is called) or separated from the burning oil at a gravity of from 60 deg. to 62 deg., it is possible to produce a perfectly safe oil, cutting off even as high as 66 deg., provided it is exposed for a sufficient time

in the bleacher to permit the lighter hydrocarbons to escape; a very bad, unsafe oil can be made perfectly safe by this simple exposure to the sun until it stands the proper fire-test.

Here, however, we meet with another popular error which it is well to confute; no refiner of any standing makes oil under fire-test, it is not to his interest to do so; he would have to make a batch of from 800 to 1,000 bbls. at least, and could not escape detection and irreparable damage to his reputation; besides, benzine to-day is worth 17½ cents in New York, oil 23 cents; there is not difference enough to make it an inducement.

All the adulteration of oil is done after it leaves the refinery, and it is not there we must look for the correction of the evils of explosive oil.

That the present fire-test is by no means perfect is well known. Common standard white oil will vary in gravity from 45 deg. to 48 deg.; Baume headlight oil composed of the heavier paraffines from 35 deg. to 40 deg., and yet gravity is no guide in this matter, from the fact of light vapors being sometimes blended even with the most carefully distilled headlight oil.

For this reason the fire-test is imperfect; if used even in a gentle draft of air the light vapors arising will be carried off without flashing, and of two oils, both indicating a fire-test of say 110 deg., one may be a well-mixed combination of the middle members of the series of hydrocarbons, averaging a gravity of 48 deg. Baume, and the other a heavier oil of only 40 deg. Baume, but containing perhaps a quantity of the lighter oils which were thrown off at 110 deg.

The real test of any oil would be its analysis into its specific hydrocarbons, but this would be far too tedious and expensive for general use, and yet it should be applied to every composition intended for burning fluid, and the responsibility of making an even article thrown upon the manufacturer.

Effective legislation in this matter can readily be attained by excluding the use of any of the lighter hydrocarbons from a certain point in any composition whatever, intended for illuminating purposes; this would cover nine-tenths of the ground, as most of the accidents of this nature are caused by the fluid imitations of refined oil.

For the prevention of adulteration of refined oil itself, the strongest legislation will be unavailing unless accompanied by rigid inspection; but this inspection should be made of the oil of the dealer from whom it goes directly to the consumer; *the remedy must be applied at the right spot;* it can readily be traced back to the refiner if desired; at present oil is only inspected at the refinery where there is no inducement to adulterate.

The use of benzine and naphthaline in the mechanic arts is so rapidly increasing that the means of adulteration in this way are growing in price, and less and less desirable.

The percentage of refined has increased of late years from more careful distillation and better crudes, ranging at present from 70 to 73 per cent. of refined from crudes of 46½ deg. average gravity.

Benzine has a density of .885 at 60 deg. Fahr., boils at 180 deg. Fahr., and solidifies at 37 deg. Fahr., to a white crystalline mass.

The tar in refining is now run off to a coke in separate stills, and the coke is burned as fuel.

The percentage of refined from crude coal oil is from 85 to 95 per cent.

Refined oil from coal and shales, has a specific gravity of .824 = 41 deg. Baume.

Refined petroleum spec. gr. 800 = 46 deg. Baume.

The measurement and sale of oil by weight is a subject whose possibilities the writer thinks have not been fully considered; that it would be eminently just to all parties concerned, from the refiner down to the consumer, is shown by the simple fact that the best oil weighs the most; a light oil in the ordinary acceptation of the term will burn up quickly in the lamp and be soon gone; a heavy oil will last much longer.

Now the refined oil of commerce ranges between 45 deg. — 48 deg. Baume at 60 deg. Fahr. We have the following weights and gravities:

45°	Baume	.8066	real	gravity	50.37	lbs.	per	cubic	foot.
46°	"	.8021	"	"	50.12	"	"	"	"
47°	"	.7972	"	"	49.82	"	"	"	"
48°	"	.7933	"	"	49.57	"	"	"	"

If the barrel or package weighs 70 lbs. empty, and when filled 367 lbs., and contains 45 gallons of oil (a very little over 6 cubic feet), each cubic foot will weigh 49.5 lbs., indicating a gravity of 48 deg.

Now, the weak point in the practice of the above is, of course, the change of bulk at different temperatures, and although a table of accurate reductions might be prepared for different degrees of heat and cold, it would be apt to make confusion in many ways; but it must be remembered nevertheless, that the amount of this expansion is in the first place very slight, that the great heat of summer and the cold of winter come only at stated times, and finally that the usual allowance of 1 deg. of gravity for every 10 deg. above or below 60 deg. Fahr. can be made as at present.

The sale by weight, however, to be of any value, must be carried through the small dealer to the consumer; when the latter knew that the heavier the weight of his ordinary canful the better and safer oil he had, and the longer it would last, he would, in connection with the color of the oil, have a simple and ready means of judgment for himself which is better than legislation, or at all events a great aid to its enforcement; skilful adulteration might dissolve some heavy substance that would add to weight and gravity, but to accomplish such adulteration without detection from the ordinary tests of color, odor, and burning properties, to say nothing of closer means, would be almost impossible. Another point of some value to all dealers would be the compensation for evaporation by the increased value of the rest.

All the objections that have hitherto been made to this system, exist at present only in a different form; it is not set up as a cure for all evils, but as putting all things on a true basis, which is always a permanent one in the end; it will not remedy the difference of gauge in hand-made or even machine barrels; it will not provide for the allowance for expansion now generally made with the thumb at the bung-hole, and it would add a trifle to the cost of handling.

Take it all in all, there are few subjects that have derived less practical benefit heretofore from scientific investigation than petroleum; from the crevice out of which it is pumped to the lamp in which it is burned, learned men have discoursed profoundly, but after deducting the points rendered doubtful by their difference with each other, there was positively little or nothing left of value to practical men; in fact to those in direct contact with all its branches of production and manufacture, the study of the subject which underlies these efforts seems to have been made, as it were, at long range from some adjoining mountain top. The man of practice has outstripped in his crude but effective way the man of theory, and he has long since arrived by instinct at truths which the latter is slowly and cumbrously working out, and gravely presenting as novelties.

For this reason, much that is put forth from high quarters falls with apathy upon the attention of the workman at the well or in the refinery; he finds a lack of acquaintance with his every-day wants and troubles, and the ghostly spirit of Jack Bunsby rather too prominent; possibly he feels that if he could only meet the man who wrote it, he could in kindness tell him something he evidently did not know.

With grave appreciation of his own deficiencies and inability, the writer wishes to present this point very seriously, so that those whose words are justly valued as authority in art and science may not destroy all the force and value of the effort by an evident want of acquaintance with the progress already made, on reference to exploded phrases and ideas of earlier times.

THE COST OF STEAM.

From "The Engineer."

Hitherto the cost of steam-power has always been estimated in terms of the value of the fuel used, interest on capital, and depreciation. There is reason to believe that this system of estimating expenses is defective, and we propose to show in what way it is defective, and to suggest something better. It is defective in that it combines two very different things in a manner which tends to produce confusion, and so to retard progress. It is the practice in badly managed engineering works to take the gross cost alone of production, and to estimate the profits or losses made during the year on gross cost as a basis, without regard to departmental expenses. In well-conducted shops, on the other hand, the cost of the production in each department of every portion of the

finished machine is carefully got out. Under the first system it is all but impossible to say whether the most is being made of every condition; under the second there is no trouble whatever in ascertaining what department pays and what department does not pay. For example, it may be known that it does not pay to build a given class of engine; why it does not pay can be determined at once from a properly kept set of books. It may be that the foundry is in fault, or possibly the boilers cost too much, or, the foundry and boiler shop doing fairly well, there may be a dead loss in the fitting and erecting shops. In any case the source of evil can be at once detected, and perhaps overcome. On the gross profit and loss system it is, however, only known that building a given class of engines does not pay, and their construction is abandoned altogether, or attempts to turn out work more cheaply are made blindly and without much chance of success. Now, the ordinary way of estimating the cost of steam-power is strictly analogous to the gross profit and loss system of which we have just spoken. It is known that, say, 100 horse-power costs so much per month, and that it costs too much; but no one knows whether it is the boilers that are in fault or the engine. The steam-producing and the steam-using departments are mixed up together. Money is sometimes wasted in trying to improve boilers already as good as they can be made, while a defective steam engine is left to take care of itself. In other cases every resource of science is spent in improving the engines, while bad boilers are left to themselves. The result is alike unsatisfactory in either case. The remedy we propose is that the cost of steam-power should always be estimated as though steam were an article of commerce, made in the boiler house and sold to the engine room. The more cheaply it can be made the better, the more advantageously it can be used the better. The moment we know, however, what steam costs per 1,000 ft., say, we are placed in a position to determine in what department improvement is required, if in any; and we can concentrate the expenditure of talent and money on the proper objects, and so attain a substantially valuable result. We feel convinced that if users of steam-power would but once realize the fact that they are dealing with a fluid every cubic inch of which cost money, they would be much more cautious in the use of it, much more careful to make it cheaply, and much more anxious to utilize it to the best advantage than they are now. The true question to which we direct attention is not how much coal is burned per horse per hour in any establishment, but how much per 1,000 cubic ft., or per pound, does the steam used cost; and how many cubic feet, or how many pounds of steam are required per hour, month, or year to do the required work?

It is to the last degree improbable that the present excessive price of coal will be maintained, but it is at least equally true that after some fluctuations coal will settle down to a price considerably in excess of that which has been paid for it for several years past. We shall probably not be far wrong if we take the future price of good steam coal, in manufacturing districts, at as much as 15s. per ton as against 10s. to 12s. hitherto paid for it; of course everything will depend on the proximity of the pits, but 15s. a ton will serve as a basis, applicable to many districts, though obviously not to all. For the moment we shall neglect the cost of boilers, depreciation, interest, etc., because they must vary very much indeed under the influence of diverse conditions. Now let us suppose that a manufacturer, or mill owner, obtains all the steam he needs from five double-flued boilers, each working up to 100 horse-power; let us see what his steam is likely to cost him. We shall assume that each boiler evaporates 60 cubic ft. of water per hour, under a gauge pressure of 60 lbs. on the square inch. The volume of steam at this pressure is to water as 350 is to 1. Therefore each boiler must produce per hour 21,000 cubic ft. of steam, weighing approximately 3,750 lbs. Assuming that the boilers are much better than those of the double-flued type usually are, we shall say that for every pound of coal burned we get 8 lbs. of steam. Then the cost in coal of our 21,000 cubic ft. of steam is 468.75 lbs., which at 15s. a ton represents in round numbers 3s. 1d. In other words, steam under these conditions costs as nearly as may be one penny three farthings per 1,000 cubic ft.; or one penny for every 100 lbs., if, as is more convenient, we estimate by weight instead of by measure. As the pressure we have named is that perhaps more extensively used in mills than any other, and as good Lancashire boilers will sometimes, and possibly ought always to

evaporate 8 lbs. of water per pound of coal from a temperature of 120 deg. or so, we may we think take one penny per 100 lbs. of steam as representing a fair standard applicable to most stationary boilers. To this must of course be added the cost of stoking, interest on capital, repairs, and other items, which will vary very much, and which we shall therefore say nothing about.

Having thus obtained some idea of the cost of steam, we may now proceed to consider how this knowledge may be utilized. Any manufacturer can determine for himself from these data and a few indicator diagrams whether in the first place his engines are working as economically as can be expected, whether they can be improved, whether the boilers are quite efficient, or whether they want improvement. In a word, he can say whether he can supply steam to the engine-house at a less price than one penny per 100 lbs., and he can ascertain whether or not the steam is supplied as cheaply as possible to the engine-house, and is wasted there. Let us assume again, for the sake of illustration, that the five Lancashire boilers of which we have already spoken supply steam to a pair of condensing engines working up to 500 horse-power indicated. The whole weight of steam sent to the engine-house per hour is 18,750 lbs., value 15s. 5½d.; dividing 18,750 by 500 we find that the engines use 37.5 lbs. of steam per hour per horse; which is a very bad result indeed, the figures showing at a glance that the steam is not used to advantage, although the price at which it is supplied to the engine-room is high. Suppose, however, that instead of using 37.5 lbs. of steam per hour, it was found that the engine used but 25 lbs., what follows? The engine which will give an indicated horse-power for 25 lbs. of steam of 60 lbs. pressure is abnormally good, so good that it would be hopeless to expect to save more than 2 lbs. per horse except by augmenting the pressure, and possibly introducing evils in the way of irregularity of motion, due to a large measure of expansion, which would be intolerable. Now 2 lbs. represents a saving of approximately one-twelfth on the cost of each horse-power. As 100 lbs. of steam costs a penny, one farthing's worth of steam must be used per indicated horse-power per hour; reducing this by one-twelfth means in 500 horse-power a saving of 10½d. per hour, which will be reduced by the fact that the improved engine will probably cost a great deal more, in the first instance at least, than its less economical predecessor. A sensible man will most likely argue, under the circumstances, that his steam is used economically enough in the engine-room, and instead of endeavoring to improve his engines, with the probability that his efforts will be useless, he will turn his attention to reducing the cost of his steam. If he pays but a little attention to facts he will soon learn that good boilers will produce as much as 11 lbs. of steam per pound of coal. The adoption of such generators in lieu of his Lancashire boilers would at once be followed by the reduction of the cost of each 100 lbs. of steam from one penny to less than three farthings, and instead of a saving of 10½d. per hour—the most that was to be anticipated from an improvement in the engine—he could effect a direct economy of about 2s. 7¾d. per hour, and this without incurring any risk in the way of extra pressure or expansion, by having better boilers. Do we not gather from these facts the lesson that attempts to improve on existing steam engines of a high class are simply waste of money while boiler engineering remains in its present condition? It is as though a farmer spent a fortune in manuring and improving land already in the highest condition, in order to extract a shilling's worth more produce from each acre in the year, while he left unreclaimed a large tract of land which required nothing but a few drains and a little lime to increase its annual value four or five fold. This rabid desire for improvement in the engine, while the boiler is neglected, is about as sensible as would be the conduct of a miner who spent days and days in washing the very best grains of gold out of the sand of a stream while nuggets are to be had for the seeking higher up the torrent.

Any employer of steam-power can discover at a very moderate outlay how much he is paying for each 100 lbs. of steam he uses in his mill or his factory. It is only necessary to measure the water fed into the boiler for about nine hours with care, and to weigh the coals burned in the same time. Once in possession of the information he can thus obtain, he is placed in a position to determine whether or not it is worth his while to attempt to effect improvements. We have met with cases where it was known that power cost much more than it ought. It was believed that the boilers were in

fault, and the engine very good. A test such as we speak of was carried out, and proved that the boilers were by no means to blame, while the engine was all wrong. A general overhaul was the result, and a few judicious alterations in the valve gear, and a slight augmentation of pressure, effected a saving of nearly 20 per cent. in coal bills. As a rule, however, boilers are more defective than engines to an extent which few people realize; and it is to the general improvement of steam-boilers that we must look for the best means of avoiding the losses due to the rise in the price of coal, which will otherwise be incurred by manufacturers and other employers of stationary engines. The subject is one of immense importance, and we shall make no apology for returning to it again, begging meanwhile to assure such of our readers as may feel disposed to consider what we have just written as very trite and common-place that we have excellent reasons for believing that the great body of steam users are wasting thousands of pounds annually by using inefficient boilers, and that they do this in complete ignorance of what they are about. Our purpose is gained if we can in any way dispel this ignorance by getting those who use bad boilers to think for themselves—to realize the amount of their losses, and to adopt the best means in their power of avoiding them in future.

BONDING IN THE SKEW ARCH.

By M. DE LA GOURNERIE.

Translated from "Annales du Conservatoire."

In considering the conditions of equilibrium of a work of masonry in cut stone, we must first determine whether all parts are subjected to forces of pressure only, or some resist efforts of extension. In the first case the bond has no influence upon the pressure developed, unless the masonry is subjected to unequal settling.

The voussoirs are often subjected to tensile forces, either because they have brackets, or because they act as ties or lintels. In this case the bond affects the pressures; for it is evident that a piece under tension cannot be divided without modifying the conditions of equilibrium. Everybody knows that a *plate-bande* does not act like lintel.

Let us first consider a mass of masonry subjected to compression only; and suppose that it acts on an abutment without projection and supporting a vertical load. All pressures are transmitted to the foundation and produce a thrust.

If the bed of a course is inclined, the upper part will tend to slide and the lower portion will be thrust in an opposite direction. This effect, too well known to require analysis, indicates a thrust toward the intrados.

Forces of this nature exist, whatever the nature of the construction, in all instances in which the course beds are not normal to the pressure.

The thrusts are independent of the bond; in whatever manner the stones of a pier are disposed, if the masonry stands, the charge upon the foundation will be the same.

The thrust inward results from a primitive fault in construction, or from the fact that an accidental load modifies the directions of the pressures.

If the stones are polished and set without mortar, slight thrusts inward will serve to destroy equilibrium, and the structure will not bear accidental loads at abnormal inclinations. But in the ordinary conditions of masonry there will be no harm from pressure slightly inclined to the beds.

As to the admissible inclinations, we recall Perronet's rule, that the voussoirs of a right arch do not need support by centring when the horizontal angle is less than 39 or 40 deg. The cohesion of mortar of course increases the difficulty of sliding.

It appears not to be possible to fix in any general way a practical limit for the angle of the bed to the ordinary direction of pressure. For different constructions are very diversely conditioned by accidental loads, shocks, and defects in bonding. The question must be considered for each kind of work, and for the various methods of bonding for the same work.

Molecular mechanics in its present condition cannot determine the direction of pressures at the various points of an arch. Experience has supplemented theory; and architecture furnishes proved constructions, from

which we determine with sufficient exactness the direction of pressures in ordinary cases of actual practice.

It is known that a horizontal right cylindric arch develops compression only. Experience shows that if the external loads are not very unequally distributed, the conditions of equilibrium are practically satisfied by making the planes of the joint surfaces parallel to the faces, and by making the planes of the bed surfaces normal to the intrados cylinder and following the rectilinear generatrices. It is inferred that at every point the pressure is sensibly parallel to the intrados, and this hypothesis has all the exactness necessary for questions in stereotomy; and it may be assumed as the basis of the geometric theory of bonding.

But if the rise is small in comparison to the span, a different hypothesis is made, which leads to the bond *plate-bande*. Experience furnished by good constructions makes us acquainted with the limit at which we should cease to bond normal to the intrados.

In most arches, properly so called, compression only is developed. The beds should be set normal to the direction of the forces and the joints corresponding with it. It follows that the angles along the edges of intersection for beds and joints are sensibly right angles. And generally the angles at the edges of the soffit are right, because the pressures are very often considered as parallel to the intrados.

In the majority of cases the right angle is the consequence of the conditions of equilibrium; but of itself it is not effective to produce equilibrium, so that a case may be imagined in which such adjustment would be worthless.

Each voussoir of a plate-bande has an acute and an obtuse angle, because the pressures are not parallel to the soffit plate which forms the intrados. Acute angles are employed in ogives, because the beds of the small arch are necessarily oblique toward the intrados of the larger; also in arriere voussoirs, because the layers are flat and cannot meet the intrados normally at every point.

When the pressure is not parallel to the face, two cases are to be distinguished, which are known as *de surplomb* and *de fruit*, with reference to a wall under vertical load.

For an example of the first case, suppose a compound corbel, each stone of which is a corbel, supporting a vertical pressure. If the beds cut the profile at a right angle, the vertical pressure would cause a thrust outward. But if the beds are horizontal, it would be difficult to shape and conserve the acute angles at the profile. Hence, *redans* are made which serve for ornamentation.

Take the case of a wall having considerable *fruit* and not supporting vertical load. If the beds are normal to the face, the upper layers push the lower outward and themselves slide inward. The disposition in this case is faulty; but when the inclination does not extend far from the face, the wall being thick and the foundation firm, the equilibrium may not be destroyed.

In a good construction the beds should be horizontal; the difficulties presented by acute angles are overcome by corbelling.

Arches with a slight skew are very ancient. They were made with horizontal courses, just like those of right arches, but cut obliquely by the face-planes. Experience shows that these had great stability.

It is very easy for each hypothesis with reference to the direction of pressure, to determine the conditions of equilibrium and what modifications are made by the kind of bond.

Some engineers think that the pressure at every point is the plane of right section. If so, the bonding of the face should be like that of corbelling at an acute angle on the side of the abutment, and like that of a wall with batter on the side of the obtuse angle. Hence the stability would be diminished by setting the beds with reference to the face; they should be perpendicular to the planes of right sections, and the corbelled voussoirs should be of large dimensions especially *en queue*. If certain angles are very acute the voussoirs should be disposed so as to form a series of redans.

Very different consequences follow, if, as other engineers maintain, the pressures are parallel to the faces. In the bond, according to this hypothesis the beds should cut at right angles the planes parallel to the faces.

By examination of the results of experience, we may determine the law of the direction of pressures with sufficient approximation.

The right bond indicated in the preceding article is very good for small obliquities, nearly to 65 deg. Arches with great skew have been made only by making the beds near each face

normal to the plane of the face. This disposition was employed in the first bonds special to oblique arches; among these may be mentioned the *biais passé*, the *joints brisés* of Gauthey, and the *intrados coudé* of Perronet. Experience condemns the hypothesis of corbelling, *i. e.*, that the pressures are parallel to the face.

This method of considering the direction of pressures guided engineers in their researches until the development of means of communication, and the consequent difficulties compelled the construction of bridges with obliquities for which the known bonds were not sufficient. The attempt has been made to construct beds with tangent planes perpendicular to the faces. That is, it is assumed that throughout the arch all pressures are parallel to the faces.

The exactness of this hypothesis has been questioned. It has been proposed to divide the arch into independent zones by planes parallel to the faces, to assure equal distribution to the abutments; but comparison of results obtained with and without this method show that the division is not necessary; and we may regard it as established that in a skew arch of ordinary dimensions, the pressures may be regarded as parallel to the planes of the faces.

This law, again, is not rigorous, and does not apply to the central portion of a very long skew arch.

Such is the consequence which follows the results obtained in the construction of skew arches. Theory must be based on these results. It must be added that experiments show that the pressures are sensibly parallel to the intrados, as in the case of right arches. In the ordinary proportions of oblique bridges the thrust toward the interior of the arch is not to be feared; and if the beds are made normal to the soffit, it is that the voussoirs by their form may be in the best conditions of resistance.

The pressures being parallel to the planes of the face, the bed should have its tangent planes perpendicular to the faces; it should also meet the intrados normally. These conditions determine a cylinder which has for directrix a trajectory orthogonal to the sections of the intrados made by planes parallel to the faces.

Considerations relative to facility of plotting and construction change the cylinder to a gauche surface; and in most cases helices are employed instead of orthogonal trajectories. The orthogonal and helicoidal bonds are the only ones employed in large skew arches.

Each is characterized by the nature of its course, and comprehends several varieties. The principal differences concern the form of the right section of the intrados, and therefore, that of the curve of the face, the exact nature of the beds, and the disposition of the joints.

The development of the skew arch in France has been historically as set forth. It has been but slightly different in England; but success has been attained by application of the same principle; the beds, being a little nearer perpendicular to the planes paralled to the faces.

Engineers who have given attention to the skew arch do not all reason according to the above principles. Some think that the bond determines the direction of the pressure; others, that the pressures are developed in the planes of the right sections and produce an inward thrust independently of the bond. With some the whole theory seems to consist in setting the stone at right angles. Of course these diverse opinions have conducted to very different results. But all engineers, with a single exception, seek to satisfy the following conditions:

That the beds be normal to the intrados.

That they be normal to planes parallel to the faces, at least up to a certain distance from each face.

That the practical exigencies of architecture be satisfied, especially those relating to facility of construction.

The fact that these conclusions derived from different premises are almost identical, shows that the subject of skew arches furnishes certain incontestable facts, to which all must adjust their theories. The agreement upon the fundamental practical rules may be regarded as complete. The divergences result from the impossibility of fully satisfying the conditions just mentioned, and from the differing opinions of engineers as to their relative importance.

When mention is made of planes parallel to the faces, they are supposed to be vertical, as is the fact ordinarily; if they have batter, this will not change the surface of the beds sensibly, because it is intended that the bond shall equilibrate the forces due to the action of gravity, and not depend upon accurate adjustment of angles.

Orthogonal bonding presents undoubted advantages, when compared with helicoidal,

with respect to inward thrust; but the latter is generally preferred on account of easier construction. The beds are identical, and consequently the same templet, helic, and gauche rules serve for all the voussoirs, which makes the cutting and verification of the stones comparatively simple. The courses have a constant thickness; all that do not stop at the imposts comprehend a voussoir at each face; their lines are obtained upon the centres by means of long flexible battens, and the determination of the angles is easy and admits verification.

An elliptic helicoidal bond is one in which the intrados forms part of an elliptic cylinder, whose lines of coursing cut the generatrices at a constant angle. The face curve is generally a semicircle, and the right section is the arc of an ellipse of which the major axis is vertical. The beds are not the same, and the tracings are not so simple as in case of the proper helicoidal bond.

In all these dispositions, the beds have the same relative positions to the faces, and the planes parallel to them. The only exception is when the skew arch is very long; in this case the part near each face alone has the bond of an oblique bridge. The helicoidal courses connect by broken joints with the horizontal courses of the central portion of the arch. A special bond may also be employed, called the *orthogonal convergent*, in which the beds develop from one face to the other without abrupt change of direction. Various rules have been given assigning the extent of the skew portion.

Some engineers are of opinion that in an arch of ordinary proportions the bond may be as in a right arch for a small space between the faces; but certain real disadvantages would result from this.

Generally, skew arches have cut stone only in the faces. The interior masonry being of brick or of rough-cut quarry stone, admits the helicoidal as readily as the right bond. The body is made of cut stone only when great solidity is required, or for appearance, when the arch is to be seen from below; but in any case the full skew is preferable to the mixed bond.

Large skew arches have been constructed since the time when the beds were made normal to the planes parallel to the faces. The first bridges in which this principle was applied probably were those in Kildare, built about 1787; one of them, at Finlay, had an obliquity of 39 deg. In 1830 an oblique bridge of 27 deg. was built over the river Gaunless, on the railway from Stockton to Darlington.

Hart's work contains a plan and description of a bridge of 25 deg.; but nothing indicates that it was built. Still, engineers think that these skew angles may be surpassed.

There was a time in the construction of railways when engineers seemed not to consider any skew an inconvenience; but this is changed. And rightly; for great obliquities involve great expense; and the voussoirs at the face present difficulties independent of the bond. Engineers now avoid them, not passing a limit of 45 deg. except under compulsion. Still, we may be assured that the principle of normality of beds to planes parallel to the faces allows approach to the most extreme cases. We know of no bridge of a skew greater than 64 deg. built on any other principle.

Experience shows that well constructed skew arches are as durable as right arches, and that they are competent to bear the ordinary loads and vibrations of the most frequented roads. The law of parallelism of pressures to the faces explains this result, showing that in the two methods the conditions of stability are analogous, if not identical.

SHIPS AND SHELLS.

From "The Engineer."

The superabundant proofs which exist that the stud or "Woolwich" system of rifling heavy guns is a disastrous failure, render it to the last degree unlikely that the system can much longer be retained in the service. Indeed, there is good ground to believe that early in the ensuing year, the whole subject of rifling heavy guns will be brought before Parliament in a way that will compel the adoption of some less defective arrangement for imparting rotation to heavy shot. Naval men and artillerists alike admit that, even with their existing imperfections, guns are more than a match for ships. With the introduction of an improved system of rifling, ships will be in a

worse plight than ever, because the power of the gun will be augmented, not only directly as regards the power of punching armor at long range, but indirectly as regards the use of shells with percussion fuzes. It has been demonstrated over and over again that no ship in the world can withstand the attack of our 35-ton guns at ranges as great as 1000 yards. Indeed, very few ships, if any, are quite impregable to the 25-ton gun at that range. Armor thus becomes worse than useless, because it enables us to explode shells which otherwise would pass through the sides of a ship without doing much injury. The destruction wrought by a broadside of carronades in Nelson's time would be infinitely more terrible than the consequences to a modern unarmored ship struck by a 600 lb. shot, or a shell which did not explode. We have frequently called attention to this fact, and urged its importance upon those who design ships of war. But eminent authorities now assure us—and we see no reason to doubt their accuracy—that fuzes can be used with an improved system of rifling which will explode a shell on striking a plate less than one-fourth of an inch thick. If this be true, an unarmored ship would be converted into a shambles before she was five minutes in action. Hitherto percussion fuzes of sufficient delicacy to insure explosion on impact with bodies offering small resistance could not be used with any certainty as regards the results. They almost invariably exploded either in the gun or immediately beyond the muzzle—in either case being, of course, useless for the required purpose. With an improved system of rifling, ye shall have a practicable, delicate, percussion fuze, and then woe to the unarmored ships. But the armored ships are no better off. If a shell once gets between decks, or into a turret, and explodes, the effects will in no case be modified by the thickness of the side through which the shell has just passed. If there is any difference it will be in favor of the thin ship, as a portion of her side would probably be blown out, and the force of the explosion wasted a little, instead of being all concentrated between decks. The designers of war ships are thus caught between the horns of a dilemma, which may be stated thus: An armored ship is even at distant ranges not safe when attacked by heavy guns firing shell, and being loaded with plating, she cannot steam very fast, nor carry coal for prolonged cruises. Still, at extreme ranges, her crew are quite protected, and she can approach tolerably near to any ship or works not defended by the very heaviest metal. The unarmored ship, on the other hand, being burdened with no plating, can be endowed with immense speed, so that she can fight or run away as she likes. She will sail well, carry coals for long voyages, and a tremendous armament; but a single shell fired at long range may utterly destroy her. Which, then, is the best ship to build? If the present system of rifling were retained, it is beyond question that a considerable number of large unarmored ships might be added with advantage to our navy; but it is clear that the introduction of an efficient percussion fuze for heavy shells alters the whole aspect of affairs. Unarmored ships will be placed at such a disadvantage that it is doubtful if they would prove of the least value in warfare. It has been shown, however, that armor to be really efficient must be so heavy that ships, like knights of old, are ready to sink under the weight of their harness. Shall we assume, then, that the guns have the best of it forever? By no means. "Hope springs eternal in the human breast;" and we hope it may yet be shown by experiment that shells may be practically set at defiance by improved methods of constructing ships. The scheme to which we once more call attention has been repeatedly discussed, but no experiments at all conclusive have ever been carried out to test its value.

Let us suppose that a 25-ton gun has opposed to it at 1,000 yards range a target made of two superimposed plates, each 4½ in. thick, and 18 in. of backing. It is well known that the gun would plunge its 600 lb. shell through such a target with the utmost ease. Let us now suppose that the two 4½ in. plates, instead of being superimposed, are put up at a distance of some 20 ft. apart, each supported by a thin backing of wood and skin plate; it is almost certain —we say almost for reasons which we shall explain in a moment—that a 600 lb. shell could not be got through the second plate at any range. The moment the shell struck the first plate it would be exploded, and nothing but *mitraille* would hit the second plate. The pieces would be easily kept out by a very small thickness of iron. We have said that it is "almost" certain that the shell would not get through, because a suf-

ficient space must intervene between the two plates to permit the destruction of the shell to be accomplished by its own bursting charge, and in the absence of the data supplied by experiment, we are unable to say whether 20 ft. would suffice for this; our impression is that less than one-fourth of the distance would suffice.

If our reasoning be accurate—and no one so far as we are aware can prove that it is not, or knows more about the matter than we do—then it follows that it will be comparatively easy to set shells at defiance; ships will carry two coats of mail, neither very thick, a space of 5 ft. or even 10 ft. intervening between them, at least above water. The space might be utilized in various ways until the ship went into action; the outer armor would act the part of a shell breaker, and would suffer heavy damage no doubt in action, but so long as it remained strong enough to insure the explosion of shells on striking it, the crew might laugh shells to scorn.

We are by no means oblivious of the difficulties which would have to be encountered in carrying the double system, as we may call it, into practice; but we believe that these difficulties can all be overcome. The obstacles which stood in the way of adopting any kind of armor-plating were at one time—and naturally—looked upon as insuperable; but every maritime nation now possesses iron-clads, and we hold that the difficulties standing in the way of the adoption of the double plate system are in no way so great as those encountered and overcome in the construction of such a ship as the Warrior. It is certain that there is sufficient promise in the scheme to render experiment not only justifiable but desirable. We all know that a 600 lb. shell could not be got through two 4½ in. plates standing one behind the other with 100 yards of space intervening. We also know that if two 4½ in. plates touch each other the shell goes through with the greatest ease. What we want to know is the point between absolute contact and 100 yards, at which the second plate must be fixed to enable it to resist shell. If this point is anywhere not more than 10 ft. distant from the front plate, then ships can be built to set guns at defiance. If the distance nearly approach half the beam of a practicable ship of war, then this plan is useless. We have already stated our opinion as to the distance that would be required to insure safety.

The Shoeburyness programme much needs the infusion of a novel element. There are no new targets tested nowadays, because there are no new targets worth mentioning. We venture to suggest the propriety of testing the value of the double skin system at the first opportunity by setting up four or five 3 in. plates at intervals of 5 ft. apart, and firing shell at them from the 12-ton gun, in order to ascertain how many plates a shell can get through. The experiment would cost very little, it would be quite new, and it would supply information of very great practical value. Of course there are preconceived notions that the "thing would not do." There always are preconceived notions in the way of improvement. We confess that we shall continue to believe that the thing would do, until direct experiment has proved that we are wrong.

COMPRESSED AIR ENGINES, AS USED FOR HAULING AND PUMPING UNDERGROUND AT THE THORNHILL COLLIERIES.

From the "Mining Journal."

The discussion of a paper on the above subject, the joint production of Mr. W. P. Maddison, mining engineer, and Mr. Farrar, of Barnsley, was resumed at the meeting of the Midland Institute of Mining Engineers held at Wakefield. The paper was considered one of the most valuable and elaborate which has been read before the Institute, and as we gave a *resumé* of it at the time from its importance to the mining community, we propose to give the opinions relating to the subject of some of the leading engineers, as well as some further experiments made by Messrs. Maddison and Farrar at the previous discussion. Mr. Hopton of Barnsley, said that it was *prima facie* evident that air, which, when just compressed, had perhaps a temperature of about 100 deg., and after flowing a certain distance was then found reduced by 50 deg., must have suffered some loss of elasticity; were the temperature of the air in the com-

pressing cylinder made sensible by the compression—conserved by any means till its arrival at the air-engine—it would then disappear in the cylinder as heat and be transformed into work, the original temperature being restored without loss of heat or energy. As to whether the heat engendered did not in a great measure indicate the accumulated pent-up power, might be answered in the affirmative, and most accurately so, provided that the engendered heat was also pent-up. When that heat was allowed to escape it showed that there was a want of power at the air engine, or an increased expenditure of work in the first instance. The experiments made proved that heat was another form of energy; consequently, as the engine was having power put through it, there was no alternative but for its entire reproduction as heat when no mechanical work was being done. Heat, therefore, must be evolved during the continuance of the work which was producing it, and the temperature, as a natural result, would rise, until, eventually, it was diffused and absorbed by surrounding substances as fast as it was produced. Motion of masses must communicate either massic motion or atomic oscillation in the interior of masses; whilst, on the other hand, if atomic oscillation was lost during storage or transit, it could not be transformed into motion of masses according to the first law of thermodynamics. If heat was lost by absorption atomic oscillation would also be lost, and the result would ultimately be loss of massic motion, with a corresponding non-utilization of the original power. Therefore, if that loss of heat corresponded in value to what a neighboring substance had gained, the correlated loss of power would = W t S $\times$ 772 foot-pounds, where W = the weight of the substance, T = its gain of temperature presumed to be equal to the loss by compression, and S = specific heat of the substance in question.

Mr. Warburton remarked that the authors stated they had a very strong opinion on the question of the loss of power by the development of heat, as deduced by Mr. Warburton in his paper, and it was determined that a set of experiments should be made, with a view of eliciting data on which to form a more decided opinion. An experiment of 30 min. duration, with air blowing off at 15 lbs., steam at 40 lbs., resulted in raising the temperature of the cylinder, compressing the air 63 deg. Fahr., and the air in the receiver 10 deg. Fahr. In the second experiment the air was blowing off at 30 lbs. pressure; outer temperature, 40 deg.; cylinder and pipes, 47 deg.; steam pressure, 40 lbs. How long it would take to get the air up to 30 lbs. was not stated, but from the commencement of blowing off in 5 min. the temperature had been raised in the cylinder 61 deg., and in the receiver 12 Fahr. At the termination of 30 min., after blowing off the cylinder, the temperature had risen 111 deg., and the air in the receiver 24 deg. In the third experiment, the air blowing off at 45 lbs., the temperature in the cylinder was 50 deg. Up to blowing off, the cylinder air had risen 103 deg., or up to .153 deg., the temperature in the receiver blowing off at 68 deg. At the end of 30 min. the cylinder temperature had risen 49 deg. more, or a total of 152 deg., whilst the heat in the receiver had, taking it at 50 deg., risen 39 deg., and at the time No. 1 receiver registered 79 deg., No. 2 registered 47 deg., No. 3 receiver registered 44 deg., and No. 3 exhaust 19 deg. The No. 3 experiment was continued, air blowing off at 58 lbs. The first registration at that pressure was in 4 min. after the last at 45 lbs. pressure. During the 4 min. the pressure had gone up to 58 lbs., but the temperature in the cylinder had gone to 218 deg. or 16 deg., and that in the receiver to 89 deg. or 10 deg. The experiment blowing off at 58 lbs. was continued 74 minutes, with an increased temperature in the cylinder of 78 deg., and in the receiver at 23 deg. What he wanted to show when heat was given off was the amount of loss. He held there was a loss. The authors of the paper say, "Follow the last experiment through, and it would be found whilst the heat generated at the cylinder stood at 250 deg., the heat registered at the receiver, close alongside the engine, only reached 97½ deg., and the same density, or elastic force, existed in the pit at No. 2 engine at a temperature of 44 deg." Now, it was the thermal difference which constituted the loss, and the figures proved it. The speaker, by figures and quotations, contended that when they lost heat they lost power, and asked if they did not do so how did it happen that with a small loss of power by passage through the valve the heat dropped in the receiver 50 deg.? If that was not loss of heat or power he did not know where to find it. Mr. Daniel did

not think the question of loss of power by heat developed during compression required any figures to prove it. If they could develop 250 deg. to 260 deg. without any loss of power, why not develop 1,000 deg. or 2,000 deg.? If they could develop heat without power they had discovered perpetual motion. Other speakers followed at great length, and at the subsequent meeting Messrs. Maddison and Farrar introduced the result of another experiment with the engines:

Time.	Steam pressure in boilers.	No. 1 Engine.			No. 2 Engine.		No. 3. Engine.		No. 4 Engine.	
		Air pressure.	Strokes made each half minute.	Average number of strokes.	Standing.	Running.	Standing.	Running.	Standing.	Running.
P. M.	lbs.	lbs.			lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
12.45	40	60	—	—	60	—	61½	—	61	—
½	—	59	—	—	—	Full set. (55	—	61	—	59
46	—	57	—	30	—	" 43	—	55	—	52
½	—	52	25	55	—	" (39	—	46	—	42
47	—	48	23	78	—	" 36	—	40	—	Full set. (36
½	—	44½	30	108	—	+10 sec.	—	32	—	" 29
48	—	Full set. (42	26	134	39	—	—	33	—	" (26
½	—	" 44	25	159	44	—	—	28	—	27¼
49	—	45½	24	183	47	—	—	30	—	28¼
½	—	49	26	209	50	—	—	39	—	33¼
50	—	52½	23	232	55	—	50	—	—	40
½	—	55	23	255	58	—	59	—	51	—
51	—	60	17	272	57	—	59	—	54	—

The experiment was made with all engines running simultaneously, with a full load. All were started at 12.45, and a person was stationed at each engine.

No. 2 engine ran the set in 2'40", taking 316 strokes = 119 per min.
No. 3 engine ran the set in 4'30", taking 375 strokes = 83¼ per min.
No. 4 engine ran the set in 5' 5", taking 305 strokes = 60 per min.
No. 1 engine average speed, 233 ÷ 5 = 46 strokes per min.

The No. 1 engine was running at 12.45 very slowly, just sufficiently quick to keep up the surface pressure at 60 lbs. per in. The pressure at starting was a maximum pressure, because under no circumstances could all three engines (Nos. 2, 3, and 4) be required to start away with a full load, except there had been nothing done in the pit for a length of time. The figures recorded at 12.47½ show beyond a doubt that when all the engines were running with full loads, and the largest consumption of compressed air was going on, the 4½ in. pipes from the surface to No. 2 engines were too small for their combined requirements, seeing that there was a difference of not less than 8 lbs. pressure between No. 1 and No. 2. The record at 12.48 showed how almost instantly the pressure rose at No. 2, whilst at the same time there was actually a depressing influence going on at Nos. 3 and 4, proving as clearly as in the former case that the 3-in. pipes were too small for the work when Nos. 3 and 4 were hauling their sets simultaneously. Such the experiment so plainly demonstrated, that Mr. Maddison determined to replace the 3-in. pipes lying between Nos. 2 and 3 with pipes of larger dimensions. In concluding their very interesting supplementary paper, Messrs. Maddison and Farrar stated that the great question raised by their paper was whether or not compressed air was a medium for transmitting power underground, such as might be made use of by managers of collieries with safety, economy, and efficiency. In the remarks in their first paper, under the head of "Cost of Haulage," it was stated that coals should be hauled in 6-cwt. tubs, and in a seam of coal in no case exceeding 3 ft. in thickness, along one and the same road, to the extent of 100,000 tons annually, at a cost of 2.237d. per ton per mile, and consider it would be admitted that they had proved its efficiency and economy; whilst, as regarded safety, the fact was so apparent that it would be absurd to discuss it. That the subject was yet in its infancy, and was doubtless open to many and great improvements, they freely admitted. Gas jets, it was stated, applied under the exhausts of each cylinder, prevented the formation of ice.

THE MODERN USE OF ZINC.

From "The Architect."

In France, Belgium, and Germany, the area of roofing anually covered with zinc is from 40,000,000 to 50,000,000 sq. ft., and the experience of 50 years shows that it forms a perfectly sound and nearly imperishable roof-covering. In this country its use is unpopular, if we may use the expression, and mainly, we think, because the principles upon which it should be used are yet hardly understood. When first introduced, about the early part of the present century, there were no English workmen who thoroughly comprehended the nature of the material with which they had to deal, and a special knowledge is absolutely necessary. In the first place, the expansion and contraction of zinc under atmospheric influences are greater than those of other metals in ordinary use. Copper, which is very efficient, but rarely used on account of its cost, approaches it most nearly, but the expansion and contraction of zinc is, *pro rata*, nearly one-third more than that of copper. Therefore in the construction of drips, laps, and other uniting points, it is necessary that, while being sufficiently sound to keep out the weather, a certain "play," to use the technical phrase, should always be allowed. Any attempt to solder together a zinc roof into one homogeneous body is certainly followed by buckling, cracking, and failure, and this was a fruitful source of trouble in the earlier transactions. Another mistake made was, that the zinc was used too thin. The process of oxidation which this metal undergoes is peculiar. The rusted surface does not rub off or blow away, but forms a sort of hard crust of enamel upon the surface of the metal, and, when laid upon boarding which is or may become damp, or exposed to steam or condensation from below, it rusts on both sides. The thin zincs first introduced into this country in this way were rusted through; they then became brittle, and failure was the result. But if the zinc be of sufficient thickness, after a certain period of time oxidation ceases, and we have a body of solid, sound metal, encased above and below by a solid coating thoroughly impermeable to the accidents of weather or temperature, and which requires no painting. To give the exact figures as described in the trade, No. 9 gauge is too thin, and perishes. No 14 gauge may be generally recommended as sufficient.

There are various ways of laying the zinc. First, it may be laid in a corrugated form without boarding, the trusses of iron or wood of the roof carrying the weight; or one may lay it in what is called the Italian style, on rafters about 1 ft. more or less apart, with a corrugation at each rafter only; or, in a third manner, upon a general surface of boarding, in the manner of a lead flat, the necessary drips, ridges, etc., provided for in the construction, with the extra allowance for expansion and contraction which the peculiar nature of the metal requires.

Machinery is extensively used in the manufacture. The zinc itself (of which the best quality is manufactured abroad by the Vielle Montagne Company, and known as "V. M." zinc) comes over in sheets of various gauges, about 8 ft. long by about 3 ft. wide. This is made into the various forms required for laying at the factory, before it is sent on to the work for fixing. Benches, some of them as long as 12 ft., are fitted with long falling plates (in action they may be discribed as a long and narrow guillotine); and taking the case of forming a roll for a roof, the sheet is placed upon a flat bench, with its edge nicely adjusted under the long falling slide. This is then forced down with a powerful screw; and, with certain detail appliances which we need not describe, the roll is formed upon the edge of the sheets. A modified application of the same principle, a long falling press, is used in the manufacture of O. G. and trough or semi-gutters.

In other cases, where ornamental forms are required, such as lions' heads, rosettes, or any similar architectural decoration, the work is done by stamping; a mould and reverse are provided; the zinc is stamped to the required form and outline, in as many pieces as may be requisite, and then the various parts are soldered together, and sent away ready for fixing. Any description of architectural decoration, guilloches, enrichments of all kinds, crockets and rosettes for Gothic work, can thus be efficiently carried out, and, supposing only that the thickness of zinc used in the first in-

stance is sufficient, may be considered as practically imperishable. We may quote the large mouldings and pediments of the Albert Hall, twenty large towers on the Marquis of Westminster's estate, the Belgrave Mansions, Grosvenor Gardens, and the Alliance Bank in Threadneedle street, as examples of decorative zinc roof ornamentation, each differing from the other in style and character.

The objections usually entertained to the uses of zinc we may fairly ascribe to prejudice. When first introduced into this country, there were no skilled workmen who understood the material, and consequently "tinmen" were employed; they, not understanding the nature of their material, used the zinc too thin, and soldered a roof up together in one piece—like a teakettle; hence much of the modern objection to its use, which, however, is rapidly being overcome. Its lightness is its great recommendation, nobody doubts its being much cheaper as a material for a roof than lead; but the public have yet to be convinced that when judiciously employed under competent supervision it is even more durable. The experience of 50 years in Continental works justifies this assertion, and there is still a farther more important saving in the scantling and general construction of the roofs where it is used.

The manufacture is to a certain extent modern, especially with us. Everything, of course, must have its beginning; but with due regard to the various points we have already mentioned, we see no reason why a zinc roof should not be the cheapest, lightest, and most durable, when properly employed, of all the materials we have at our command; while the examples we have already quoted show the facilities it affords for architectural decoration of the highest class.

ON THE DISCHARGE OF RIVERS AND OTHER CHANNELS.

By WALTER R. BROWNE.

From "The Engineer."

The July number of the "Philosophical Magazine" contains an article written by the late Canon Moseley, and forming the conclusion of a series published by him on "The Steady Flow of a Liquid." These papers deal with all the ordinary cases of the flow of water through long channels, namely horizontal circular pipes supplied from a reservoir, inclined pipes, closed channels of other forms, and, lastly, open channels of any geometrical section. The question of the discharge of water under these various circumstances is, of course, one of the first importance in hydraulic engineering. Much has been written on the subject, and many tables and formulæ published from the times of the old French and Italian engineers to our own day. All these, however, are professedly founded merely on experiment, and are open to the objections which always attach to purely empirical results. Moreover, such experiments are difficult to make with sufficient accuracy on a small scale, or to make at all on a large one; especially with such apparatus as was at the command of those older investigators to whom most of our formulæ are due. Canon Moseley was, so far as I know, the first who attempted to construct a theory of the flow of water in these cases, at the same time using experiment throughout to verify his results. His method is that of the conservation of energy, and is based on the proposition that, the motion being uniform, the work done by the head of water which causes the flow must equal the work done by the several resistances which impede it. To verify his results he has had recourse to the elaborate experiments made at Paris by MM. Darcy and Bazin, and recorded in the two following works:—"Recherches expérimentales relatives au mouvement de l'eau dans les tuyaux." Paris: Bachelier, 1857; and "Recherches Hydrauliques," par M. Darcy, continuées par M. Bazin. Paris: Dunot, 1865. These experiments, amounting to many hundreds, are far in advance, both in number and accuracy, of any previously existing, and offer a very wide field for the verification of any formulæ that may be proposed on the subject. It is thus that they have been used by Canon Moseley. In fourteen tables, embracing the various cases enumerated above, he has compared the theoretical discharges calculated from his own formulæ with the actual discharges as determined by MM. Darcy and Bazin. The agreement, taking an average

of the cases, and considering all the difficulties which surround the subject, is exceedingly close, and quite sufficient to prove the general truth of the theory. It might seem, therefore, that all which remained to be done was to put the conclusions in such a form as would make them available for practice. This unfortunately is not the fact. The formulæ for the most part are by the nature of the case encumbered with symbols whose values are not at present susceptible of determination. These symbols arise from the consideration of three different sets of forces: (1) The resistances acting within the reservoir to check the flow of water before it enters the channel; (2) the resistance of the sides and bottom of the channel to the motion of the stratum or film of fluid passing over them; (3) the resistances of the different films themselves, moving, as they do, with varying velocities, to the passage of one over the other. None of these forces are accurately known, and the first in especial offers almost insurmountable obstacles to investigation. It is true that Canon Moseley—in employing MM. Darcy and Bazin's experiments to verify his results—has overcome these difficulties by various ingenious expedients. But these are adapted only to the case in hand, and do not assist in making the formulæ available for general purposes. The second and third difficulties disappear, however, if we suppose the maximum velocity to be known, and make it our object to determine from thence the mean velocity and the discharge. The first still remains, except in a single case—that, namely, of an open inclined channel, such as a river in which the liquid has attained an uniform depth and a steady, equable motion. Here the conditions of the flow will not be altered, if we suppose the channel to be prolonged backwards to infinity; or, in other words, they are altogether beyond the influence of the reservoir, if reservoir there be. Accordingly, Canon Moseley has devoted a great part of his third and last paper to this important case. The formula arrived at is tested by comparison with a large number of experiments, taken at random from those of MM. Darcy and Bazin; and, on the faith of this comparison, it is finally proposed by him "as representing sufficiently for all practical purposes the discharge from a stream of given section in terms of its velocity at its midsurface—that is, its maximum velocity."

It is to this formula that I wish to direct attention. In order to ascertain whether it is a real addition to our knowledge on so important a subject as the discharge of rivers and other open channels, I have sought to compare it with the formulæ already in use by bringing all alike to the test of MM. Darcy and Bazin's experiments. On consulting, with this object, the best known modern works on hydraulics (D'Aubuisson's "Hydraulics," Neville's "Hydraulic Formulæ," and Downing's "Practical Hydraulics"), I have been surprised to find on how slender a basis of real experiment the accepted formulæ rest. They appear to be derived, in the first instance, solely from thirty-eight experiments by Dubrat, on canals of which the largest was 1.6 ft. wide, and with depths of water varying from .17 ft. to .895 ft. From a discussion of these experiments Prony framed a formula—which has since met with general acceptance—for determining the mean from the maximum, or surface velocity. This formula, expressed in feet, is as follows (D'Aubuisson, Bennett's "Translation," p. 121):—

$$v = V \frac{V + 7.78188}{V + 10.31508}$$

or, in metres, as given by Neville ("Hydraulic Formulæ," p. 101)—

$$v = V \frac{V + 2.37187}{V + 3.15312}$$

where v is the mean and V the surface velocity. Throughout my calculations I have used the metrical system, as being that in which MM. Darcy and Bazin's experiments are recorded; and as the discharge equals area multiplied by mean velocity, the formula becomes, if we take S for the area,

$$\text{Discharge} = S\,V \frac{V + 2\ 3719}{V + 3\ 1531} \quad . \quad . \quad (A.)$$

For practical purposes Prony considered that it would suffice to take the mean as four-fifths of the maximum velocity, and in this he is followed by Professor Rankine ("Civil Engineering," p. 674). This gives us a formula,

$$\text{Discharge} = S\,V \times .8 \quad . \quad . \quad . \quad . \quad . \quad (B)$$

Mr. Neville ("Hydraulic Formulæ," p. 101) gives as the result of Ximenes, Funk, and Brünning's experiments on large channels, that mean velocity = .835 maximum velocity; whence

$$\text{Discharge} = S\,V \times .835 \quad . \quad . \quad . \quad . \quad (C)$$

Lastly, we have the theoretical formula of Canon Moseley. If S be the area and C the border or wet perimeter of the channel, this formula will be expressed as follows:—

Discharge

$$= \frac{C}{2S}\left\{1-\left(1+\frac{2S}{C}\right)^{\frac{-2S}{C}}\right\}V \quad \text{(D.)}$$

A comparison of these four formulæ as applied to experiments of MM. Darcy and Bazin is furnished by the two following tables. In these the values as given by experiment and by Canon Moseley's formula are taken from the paper above referred to; the rest have been calculated by myself. Table I. is from M. Darcy's Experiments, series 4. Here the channel was rectangular, breadth, 1.832 metres; inclination, 0.0049 to 1; sides and bottom covered with gravel stones (0.01 metre to 0.02 metre in diameter) fixed in cement. Table II. gives experiments taken at random from those of M. Darcy with rectangular channel of various descriptions:—

TABLE I.

Index Number.	Depth of stream.	Maximmm velocity.	DISCHARGE.				
			By experiment.	Formula A. Prony.	Formula B. Prony.	Formula C. Neville.	Formula D. Moseley.
	Metres.	Met es.	m. c.	m. c.	m. c.	m. c.	m. c.
4	0.1917	1 616	0.411	0.47457	0.45402	0 47338	0 4606
5	0.2226	1 748	0.515	0.59936	0.57027	0.59552	0.5636
6	0.2499	1 847	0.618	0.71347	0.67647	5.70607	0.6776
7	0.2782	1.964	0.721	0.84816	0.80078	0.83582	0.7627
8	0 3025	2.032	0.824	0.95643	0 90087	0 94029	0.8365
9	0.3240	2.124	0 927	1.0744	1.0086	1.0527	0.9224
10	0.3507	2 205	1.030	1.2101	1.1333	1 1829	1 0181
11	0.3737	2.323	1 133	1.3635	1.2723	1.3280	1.1253
12	0.3967	2.352	1.236	1.4668	1.3675	1.4273	1.194

Applying ourselves first to Table I., it will be seen that the experiments were made on a stream of about 6 ft. in breadth and from 8 in. to 13 in. in depth, flowing through a channel of gravel set in cement, with velocities varying from about 5 ft. to 7 ft. per second. It is therefore a very good representative of rapid stream flowing over a gravelly bottom. On comparing results, it appears that formula (A) is altogether untrustworthy, giving values much in excess of the truth. Mr. Neville's formula (C) also errs considerably on the same side. Prony's formula (B) and Moseley's (D) are about equally accurate in the first three cases, but in the last six Moseley's comes very much the closer of the two, and, in fact, is the only one of the four that can be considered satisfactory. As in these latter experiments the depths are greater, it may reasonably be inferred that Moseley's formula is more accurate with a deep stream; but another cause is probably also at work. In MM. Darcy and Bazin's work it is stated that in the three first cases the maximum velocities were observed by means of the gauge tube; while in Nos. 7, 8, 9, 10, they were determined by floats. Now, in the first three the errors per cent. in Moseley's formula are 12.1, 9.3, 9.6 respectively; while in these four they are 5.8, 1.5, 0.5, 1.2 respectively. The first three are all in excess; the latter four are two in excess and two in defect. We may hence surmise that the gauge tube is not so accurate in its determinations as are floats, and hence that the error is in part due to the experimental results, and not to the theory. However, in Nos. 11 and 12, where the gauge tube was used, the errors are still small, viz., 0.7, 3.4 respectively; and hence this surmise must be considered as probable only. Again, the errors in formula (B) are as follows in the several experiments from No. 4 to No. 12: 10.7, 10.7, 9.4, 11.1, 9.3, 8.8, 10.0, 12.3, 10.7. They are thus tolerably uniform on the whole, though with a tendency to be least where the velocities were determined by floats, and also to increase as the depths are greater. The mean of the whole is 10.3; and hence, if we take .7 instead of .8 as the multiplier of the maximum velocity, we shall have values sufficiently near for all

TABLE II.

Index Number.		Inclination of channel.	Breadth of channel.	Depth of stream.	Nature of the surface.	Maximum velocity.	DISCHARGE.				
Series.	Experiment.						By experiment.	Formula A. Prony.	Formula B. Prony.	Formula C. Neville.	Formula D. Moseley.
			Metres.	Metres.		Metres	m. c.	m. c.	m. c.	m. c.	m. c.
2	7	0.0049	1.812	0.1912	Cement (pure)	2.521	.721	.75316	0.69873	0 72930	.7096
3	7	0.0049	1 911	0.2180	Bricks laid flat	2.207	.721	.78543	0.73554	0 76773	.728
4	10	0.0049	1.832	0.3507	Gravel (0.01 to 0.02 diameter) cemented	2 205	1.030	1.2431	1.1333	1.1829	1.01727
5	11	0.0049	1.861	0.4176	Gravel (0.03 to 0.04 diameter) cemented	2 006	1.133	1.3260	1 2472	1.3014	1.0708
6	1	0.00208	1.99	0.0791	Planks	0.806	0.100	0.10186	0.10150	0.10594	0.151
7	6	0.0049	1 99	0.1851	Ditto	2.216	0.618	0.69750	0.65301	0 68158	0 6542
8	9	0 00824	1.99	0.1976	Ditto	2.847	0.927	0.97375	0.89361	0 93479	0 9013
9	2	0 0015	1.983	0.1414	Ditto	0.928	0 203	0 21040	0.20816	0.21727	0.221
10	3	0.0059	1.987	0.1297	Ditto	1.964	0 411	0.42888	0.40492	0.42264	0 434
11	3	0 00829	1.982	0.1133	Ditto	2.269	0.411	0.43612	0.40762	0.42546	0.446
12	4	0 0015	1.960	0.3110	Planks, with boards fixed across them, 0.027 metre wide and 0.01 metre apart.	1.334	0.618	0.67158	0.65052	0.67898	0.597
13	5	0.0059	1.961	0.2448		2 226	0 824	0.91341	0.85488	0.89228	0.828
14	6	0 00886	1.952	0.2524		2.747	1.030	1.1742	1.0827	1.1301	1.0407
15	4	0 0015	1 960	0.4058	The same as above, but the boards 0.05 metre apart	1.081	0 618	0.70116	0.68783	0 71793	0 5919
16	7	0 0059	1.963	0 4202		2.060	1 236	1.4446	1.3594	1.4188	1.1594
17	6	0.00886	1.951	0.3319		2.206	1.030	1 2202	1.1428	1.1928	1.0343
18	8	0.0049	1.197	0.3339	Planks	2.560	0.824	0.88327	0.81854	0.85435	0.77045
19	8	0.0043	0.800	0 3007	Ditto	2.042	0.411	0.41736	0.39298	0.41017	0.3991

practical purposes to those given by experiment.

These results are on the whole confirmed by an examination of Table II. The circumstances are there much more varied. In the first four cases Moseley's formula is decidedly the most accurate, erring—as do the others—sometimes in excess and sometimes in defect. We then have a remarkable case, Series 6, No. 1, where the discharge by Moseley's formula is half as much again as that given by experiment. It will be seen that in this case the depth is very small, being 0.0791 metre, or about 3 in.

Now Moseley's formula is based on the supposition that the motion is steady, and that the water arranges itself in "films" or similar shells of liquid one inside the other, each moving with its own velocity. But it is clear that where the stream is very shallow the inequalities of the bottom, by causing ripples, etc., will tend to prevent this state of steady motion from existing, and will unduly disturb the flow of the water. Hence the theory is not properly applicable to these cases and its values will be untrustworthy. This is confirmed by Series 7, No. 6; 9, No. 2; 10, No. 3; 11, No. 3, where the depths are small; and by 18, No. 8, and 19, No. 8, where the breadth is contracted. In these, formula (B) is the most accurate, erring, however, generally in defect, while with larger channels Moseley's formula reasserts its superiority, as in Series 8, No. 9; 12, No. 4; 13, No. 5; 14, No. 6, etc. No advantage is seen to be gained in these examples by the substitution of .7 for .8 as a multiplier of the velocity.

Much more might, doubtless, be gleaned by a more thorough analysis of these and other experiments. For the present, the conclusions which we seem justified in drawing are the following:—(1) Formulæ (A) of Prony and (C) of Neville may be rejected as inaccurate; (2) for small channels and shallow streams formula (B) is the best that can be used, but even that cannot be much relied on; (3) for medium-sized channels with gravelly bottoms, good practical results are given by taking the mean velocity to be $\frac{7}{10}$ the maximum, instead of $\frac{8}{10}$, as in formula (B); (4) for large channels it will be advisable to use Canon Moseley's formula (D) as being the only one which rests on a theoretical basis independent of the size of the channel, while at the same time this theory has been sufficiently shown by experiment on medium-sized channels to be the true one. And thus physical science may reasonably take to herself the assurance that a problem so confessedly difficult as that of the flow of water has by the last effort of one of her truest followers been fairly brought under her sway.

THE MATERIALS OF THE ARCHITECT.

From "The Builder."

Selection of materials for architectural use is a subject that so continually demands the attention of the architect, the engineer, and the builder, either directly or impliedly, that it is desirable from time to time to review our knowledge of the subject, and to seehow far new discoveries, or local or even tem porary causes, may tend to modify our practice.

The chief considerations which should regulate the selection of material for any structure are, on the one hand, hygienic qualities, durability, and beauty; and, on the other hand, economy. We place these qualities in two distinct categories, because it is thus, for the most part, that they are regarded; whether properly or improperly remains to be seen. Under the head of economy rank the questions of local convenience and supply; and these again are often closely connected with the sanitary qualities of a material, whether as a conductor or non-conductor of heat, an absorbent or non-absorbent of moisture, or with reference to qualities yet more subtle, as to which scientific investigation is yet in its infancy. But there seems to be good reason to hold that, apart from the physical properties to which we have referred, there are others the nature of which we have as yet been unable to grasp, but the effect of which is more direct on human health than may be at first imagined. We see this very clearly marked in the selection of site. Apart from any question of drainage, there is a difference, which we will, for the sake of expressing what we mean, speak of as of something resembling a magnetic or elec-

tric character, directly due to the chemical nature of the soil, which is most sensibly perceived by delicate or unhealthy persons, and which we may thus be justified in regarding as of some importance to us all. Such, for instance, is the difference experienced by many persons between residing on a clay, a sand, or a lime-stone soil. This cannot be attributed altogether to hygrometric causes. For we may instance the "rab" of Pembrokeshire, which is a species of stratified clay, so indurated that it breaks into small fragments that may be used as gravel for paths and footways. The soil above is dry from the innumerable fissures of this geological rock. And yet the peculiar effect of clay soil on delicate health is experienced by those who reside on the rab, and who give attention to such subjects. Again, those who have resided on a volcanic soil, such as the Italian *tufa*, are well aware of the extreme fatigue which attends walking on the surface. This is not a question of latitude and solar heat; for on limestone soils, in the immediate vicinity, this special fatigue is unfelt. We have here a direct illustration of the relation between soil, site, and structural materials. When, in our own country, the natural asphalts which we import are used for pavements or roadway, something of the fatigue experienced on the *tufa* soil may be detected by the pedestrian. On the other hand, a marble floor, or a marble staircase, in a *tufa* country, gives a freshness and vivacity to those who command such a domestic luxury that is well known to persons of experience; and which is not at all dependent on causes to be detected by the thermometer.

There are many things which lead us to suppose that there is something specially akin to human health in the earth, whether we regard the mass of the planet or the mixture of various elements that forms good agricultural soil. The marvellous powers of earth as a disinfectant, though long known, have been only recently brought into prominent notice. Lime and clay each has its special value; and the experiments that are in progress as to the deodorization of sewage by the admixture of these simple materials, deserve attention. Again, the benefit to health that is often obtained by sending a sickly child to follow the track of the newly-turned furrow, is not a mere result of air and exercise. The warmth and substantial comfort of a turf hut, such as those which rise like mushroom cities, along the course of great public works, cannot be spoken of as they deserve, except by those who, like ourselves, have made experience of them. They have, no doubt, like thatched roofs, their special disadvantages. We are not about to advocate a return to the aboriginal wigwam; but we say that there is so much that is good in this rudest form of dwelling, that it is well worth the attention of the builder how far earth that is thoroughly dry and protected from moisture may be rendered more available than is our present custom, for increasing the comfort and sanitary excellence of our dwellings.

Earth, it may be replied, is what we *do* use, in the greater part of England, in the form of brick. The reply is not exactly correct, as the use of clay for the material of bricks is the selection of the species of natural soil which is least favorable to human health for the staple of our building materials. Yet, even so, there are special advantages proper to brick. When well burnt, it is by far the most durable of materials. Neither metal nor stone can compare with it in this respect; and not only is this true with referance to durability, under ordinary circumstances, but it is especially true with regard to the terrible casualty of fire. It is on evidence, from the results of the operations of the Fire Brigade, that neither stone nor iron can be relied on when exposed to great heat. The stone flies, the cast iron cracks, the wrought iron bends and yields. In transmitted heat alone,—that is to say, great elevation of temperature without actual exposure to flame,—a wooden staircase has been found safer than a stone one. Solid beams of wood are considered, by the experience of the Fire Brigade, far more reliable than iron standards.

Again, the superiority of a tile roof, for the maintenance of a mean temperature in a house, over one of slate, is very great. In this case, indeed, it is rather owing to the relative thickness of the roofing stratum than to any other quality, as clay passes into slate by imperceptible degrees; but the difference in the action, as regards the sensible comfort of the inmates of a dwelling-house, of a tile roof and of a tile floor, is very deserving of attention. If the influence which is either trasmitted or arrested by the clay be of a nature akin to terrestrial magnetism or electricity, we may

form some idea why a tile roof should be a comfort and a tile floor a discomfort.

Recent improvements of various kinds, and the knowledge which the International Exhibitions have served to spread, have turned the attention of the architect to the use of terra-cotta in building, of which we have not unfrequently spoken. But it is matter of very serious regret that nothing seems to arrest the increasing deterioration of ordinary building bricks. Their extreme roughness is such as to demand a quantity of cement altogether disproportionate to that used by the old bricklayers. We use the word in its general, and not in its special, sense. With the increase in the quantity of cement employed comes an increased temptation to mix it with inferior materials. Thus the main good quality of our brick buildings, their durability and defiance of weather, is becoming seriously impaired by the struggles of the brick-maker to use every sort of earth obtainable.

The main architectural novelty of the last twenty years has been, as most of our readers are aware, the increased use of iron as a building material. This has reacted on structure, and on pictorial design. In some instances the action has been most desirable. Thus we have attained a power of covering large apertures, whether with heavy rolling weights, as in our estuary and intra-mural railway-bridges, or in the way of mere shelter, as in railway stations and slip-roofs. We find a legitimate and admirable use of iron in such structures as the Albert Hall. We regret the power of bigness which has been placed at the command of the builder in such places as the Charing-cross and Cannon-street roofs. But there are so many and so great objections to the use of iron as a building material that it is well to review them.

To a certain extent, we may speak of these objections as, in the main, economical. But economy is not all,—or, at least, the word must be taken to include the economy of life. It is only the other day that the traffic on the St. John's Wood branch of the Metropolitan Railway was arrested by some threatening symptoms in the bridge over the Regent's Canal. The company are to be congratulated on their vigilance, as one of the main evils of iron as a structural material is the entire absence of warning before fracture.

Then we have to bear in mind the constant invitation which any unprotected surface of iron continually offers to the subtle and destructive power of rust. Careful and constantly-renewed painting is of vital importance to the durability of iron. In large exposed spaces where the metal is thin and outspread, this source of danger becomes disproportionately large. Thus, on the one hand, all those fittings and ties which are exposed to atmospheric influence (as to which the fact of being under cover is not of so much importance as might be imagined), but removed from ready inspection and access, and, on the other hand, those plates and sheets which cover large areas with comparatively small weights of metal, are sources of danger which the architect who builds for posterity will carefully avoid.

Added to its structural fickleness, especially when exposed to fire, and to its liability to stealthy erosion by rust, is another peculiarity of iron that will render the provident designer very chary of its use, except in those circumstances for which no substitute can be readily procured,—that is, the great fluctuations of price to which it is subject. These amount, as we have recently seen, to 300 per cent. Fluctuations in the price of labor, and thus of materials, are among the difficulties with which the architect has always to reckon. But nothing that has yet occurred among carpenters, masons, or bricklayers, either as regards the materials on which they work or the wages they may demand, is at all comparable to the violent fluctuations that take place in the price of iron.

A further caution to be observed in the architectural employment of iron depends on the excessive variability of its tensile and compressive strength. In bar iron there is a difference in tenacity, between the best Yorkshire bar and the ordinary merchants' bar of 40 per cent. In elasticity, the difference is yet larger, amounting to 75 per cent. over the minimum, or average of from 14,000 to 8,000. In toughness, the work done in breaking a 1-in. bar, 1 ft. long, differs from 730 to 5,700, the best Yorkshire iron having eight times the tenacity of the common bar, and the disproportion in plates being even greater. Even in specific gravity differences occur to the amount of 22 per cent. It is therefore evident that, when we speak of iron, we speak of a group of metallurgic products differing, as much as if they were known as distinct metals, in all the qualities which

are of value to the architect; although they may very closely agree in one of the properties with which he has to contend, viz., liability to corrosion. Absolute test, in the case of any important ironwork, is a *sine qua non* for the engineer. And the tests, to be worth anything, must be applied either to the whole supply, or to samples selected at will by the purchaser, without any communication with the provider. We could give striking examples of the manner in which iron is got up for special testing; and we believe that Mr. Kirkaldy, the inventor and proprietor of the best mechanism employed for the purpose of testing iron of any kind, could tell much more.

But even this is not all. It is now 71 years since the first successful application of cast-iron beams to the purposes of building, which took place, according to Mr. William Fairbairn, in 1801, in a cotton-mill at Manchester, after designs by Messrs. Boulton & Watt. Tredgold's work was published in 1822. Mr. Hodgkinson commenced his well-known inquiry into the strength of iron beams in 1827; and we have a Parliamentary Blue Book, the report of the commissioners appointed to inquire into the application of iron to railway structures, which dates in 1819. Yet on a subject which certainly ought, by this time, to have been reduced to scientific certitude, we have recently seen published a new treatise, in which the author establishes at all events a *prima facie* case, to the effect that in all the wrought-iron beams that are constructed according to the *formulæ* now generally accepted, fully one-sixth part of the iron employed is wasted; while in cast-iron beams repeated applications of the recognized working loads will subject the upper flange to a repetition of the proof stress, and are thus likely ultimately to cause failures. Thus, in a word, iron, as an architectural material, is not perfectly understood in its scientific theory; is subject to a variation in price of from one to three; and to the never-failing action (unless carefully counteracted) of the corrosive elements of the atmosphere.

Our recent experience with regard to stone has been enlarged in both an upward and a downward direction. How far stone, which has not been carefully selected from a known bed, is from being a durable material, or even from equalling the durability of wood, may be estimated by any architect who will take the trouble to examine the condition of the New Palace of the Legislature at Westminster, and any of his own buildings. The most striking instance within the range of our own personal experience is the case of St. David's Cathedral. Beds of red and purple sandstone, of colors most charming to the eye, are to be obtained in Pembrokeshire, which are almost indistinguishable on inspection, when first quarried; but which differ in their durability as much as Portland and chalk differ. Nash, the architect, restored St. David's in his time. He used some of the perishable stone, and much of the restored work is more decayed than that which it replaced. Some of this stone was used in the station buildings of the South Wales Railway, to the great satisfaction of Mr. Brunel's staff in the first instance. Symptoms of decay, however, soon made their appearance; but were arrested by the application of a silicate.

On the other hand, we have recently had the opportunity of comparing the condition of massive stonework that may be definitively assigned to known dates, differing from each other by periods of 540 and 570 years respectively, the most recent of which is 1,900 years old. We refer to the results of the exploration of Jerusalem by Capt. Warren, which are such as to enable us to identify with certitude, in certain points, the work of Herod, of Nehemiah, and of Solomon. Of the former, which was constructed without cement, but with the joints strengthened by mortises and tenons in the solid stone, there are stones now *in situ*, with the quarry marks, in red paint unobliterated, in perfect preservation. There are others of the same or later date, much decayed. The result of the observation is, that in 2,800 years the difference in durability between stone from different beds in the same quarry has been such, that we have reached the limit of that of the inferior quality. It may be said that this is a long life for masonry. We may contrast it with the cathedral work to which we have before referred. The result is, that for a stone building on the durability of which the architect desires to rest his fame, the selection of bed is a matter of as much importance as the selection of quarry. No beauty of appearance, or behavior under the pick or the chisel, is a proof of durability. Actual experience of the power of any particular stratum of stone to resist atmospheric influence, can alone assure the

builder that he is working securely for the future.

It ought to be hardly necessary, in the present day, to call the attention of the architect to the extreme danger of an intermixture of iron and stone, or, indeed, of iron and brick. When brought into direct contact with mortar, nothing will prevent the slow erosion of iron. It is not necessary for the atmosphere to have access. The materials requisite to allow of destructive chemical change are to be found in the iron and in the mortar. And it is not merely the gradual disintegration of the former that is to be feared. That would be a source of positive danger, so far as the tenacity of the iron had been depended on by the builder. But the evil is active and unsleeping. Beds of rust, of three or four times the thickness of an ordinary iron plate, *grow* within the structure, with an energy as destructive as that which is exercised by the roots of plants. The marble sarcophagus of King Henry VII., is an instance of which we can speak from personal observation. Most of the metal work of the beautiful structure was either copper or brass. But there were iron plates introduced as washers between the horizontal slab and the walls, which behaved exactly as we have described. They coated themselves with beds of rust, of three times their thickness, and were, when removed, slowly shattering the tomb.

Hoop iron laid in as bond to brickwork is a not unmechanical method of increasing cohesion to a very considerable amount. But it requires care that it should not become an engine of destruction from its chemical action. Such is invariably the case when it is laid in mortar. In cement, however, the destructive action does not occur. The iron lies chemically dormant, and does its mechanical duty. But in all cases where the use of metal is absolutely necessary for the support of masonry,—as, for instance, where a delicate pinnacle, or the acute quoins of a skew arch, are pierced with a belt,—we most strenuously urge the use of copper.

We do not wish to introduce moral reflections into an architectural inquiry. But it is impossible to investigate the question of durability of building material without being struck with the immense difference in the treatment of their work by ancient and by modern builders. Men build now for a livelihood. We do not speak of this as discreditable,—far from it. Yet it *has* the invariable accompaniment of the temptation to build cheaply, and therefore not durably. The old builders wrought for durability. The Great Pyramid, or the Great Temple Enclosure, or the mysterious Stonehenge, might have been executed at the tenth part of their actual cost, and so as to have presented, when spick and span new, as brilliant an appearance as could ever have been their pride. But where would they have been now? Where will any of our public buildings be, we will not say 3,000, but 300 years hence?

FOUNDATIONS.

From "The Building News."

The ground upon which we build varies in firmness through all the degrees between solid rock and silt, but may be succinctly classed as (1) homogeneous rock; (2) clay, gravel and dry sand; and (3) silt, wet sand, and soft clay. For all ordinary structures, and for all walls except retaining walls, the foundation is required to be level. In building on rock, therefore, all that is necessary to be done is to cut it down in level benches. In building upon the second class of ground, concrete is generally used to spread the weight over a larger area than the base of the structure itself, so as, firstly, to prevent unequal settlement, and secondly, to make the resistance per square foot of a comparatively weak foundation equal to its duty by extending the area over a greater number of square feet. In the third class of ground, piling is necessary.

If we were to inquire into the precise bearing power per square foot of each particular kind of ground, we should find the variations so numerous that to apply the knowledge so acquired in practice would lead to almost interminable variations of the area of base for the same weight, often even in the same building; but we may take a general view of the nature of the ground, and judge to which class it belongs, and so determine the kind of foundation most suitable. It may be roughly stated that rock

will bear anything that can be put upon it, for leaving out of consideration the more obviously strong rocks, such as granite, basalt, limestone, and strong sandstone, even weak sandstone or weak magnesian limestone will, according to the experiments of Sir W. Fairbairn, bear a weight of about 200 tons per square foot before crushing, and if we say that one-eighth of this would be a safe load, which is that given by Professor Rankine, we may say that it will safely bear about 25 tons per square foot; and as a practical example the great chimney at the St. Rollox Chemical Works, which is 450 ft. high, presses upon its foundation with a weight of less than 2 tons per square foot, the ground upon which it is built being a soft sandstone; and we have not many buildings so high as that, although we have railway bridges in which the weight on the foundations of the piers is more than twice as much as that. Therefore, in building on a homogeneous rock, even though it be friable to the touch, seeing that it will safely carry something like 20 tons per square foot, *in situ*, it may be roundly said that it will cary anything we can put upon it.

Washed material, that is such as has been, according to the belief of geologists, disintegrated from the older rocks and washed down and deposited where we now find it, such as clay, gravel, and sand, is so various in composition, of each kind, that no statement of its bearing power can be made that would apply to all alike, and to attempt to distinguish them precisely would be practically unuseful. But there are two practical considerations which much affect the bearing power of clay and of sand. If foundations in clay are laid so near the surface as to be affected by the disintegrating effects of frost and drought, the structure will have no stability, for the dry weather and heat of sun contract the ground by evaporating the moisture from it, in consequence of which small fissures are formed, although the superficial covering of the ground prevents us seeing them in most cases, and if those fissures extend underneath the foundation, they become filled with water after rain. Then that water will be frozen if it be not beyond the reach of frost, and its expansive force will disturb the ground when the ice thaws, and this, often repeated, will cause a settlement of the foundation. In this climate a depth of not less than 3 ft. is considered to be necessary in order to be below the reach of frost, and foundations of important buildings in clay should not be laid at a less depth than 4 ft.

The other practical consideration, with regard to sand, is that when a foundation is laid upon sand, it is necessary that it be first drained, if not already dry, and that the drainage should be permanent. There is a certain dampness in sand, even after drainage, which cannot be removed, but it is not desirable that it should, even if it could, be removed. All that is necessary is to remove the excess of water, for it is excess of water in clean sand which makes it a quicksand. The dampness caused by the capillary attraction of the particles of sand amongst the interstices is rather a benefit than otherwise, for it tends to consolidate the mass by contracting the particles together, and sand in this state—which may, for practical purposes, be called dry sand, for the slight amount of water it contains will rise no higher than to the top of its own body—is a very good foundation.

The lower we go down in a bed of clay or gravel the more compact and unyielding we find it, because of the greater pressure it has been subjected to by the superincumbent material; but confining the question at present to foundations within a few feet of the surface, we shall find that the weight with which existing buildings press upon foundations of strong clay, gravel, or dry sand, is seldom more than one ton per square foot; and although the old-fashioned "practical man," who could do nothing better than copy what somebody else had done before him, is fast going out of date, it is always a useful guide, and, as it were, a test of design, to hark back to that which has already been practically done, if it were for no other purpose than to check errors of calculation. Nevertheless, this matter of the bearing powers of earth is well worth theoretical investigation. The weight-carrying power of all kinds of earth depends upon its frictional stability—that is to say, its power of resistance to the slipping or sliding of its particles upon each other; and Professor Rankine, in his "Manual of Civil Engineering," under Art. 237, says: "In earth whose friction alone is relied on for resistance to displacement by the pressure of a building, the weight of earth displaced by the foundation should not bear a less ratio to the weight of the building than that given by" the equations which he sets forth. But when foundations are to be made in such earth as we are now speaking of,

which has considerable frictional stability, it is rarely necessary to apply the principles of the article above named, because the depth to which the foundation must be sunk, in order that the building may rest on earth below the reach of frost, is always greater than those principles require.

The ground having been excavated to the depth necessary to keep below the action of frost—say, 4 ft. at the least—it would be a waste of money to fill in all this space with brickwork or other coursed masonry, and it is usual, therefore, to lay down a bed of concrete first, and to commence the footings upon that. The best material for concrete is broken stone. That is a general statement and a true one. Granite may be called stone, so may trap rock, and either will make good concrete, but the best is to be made from hard, coarse-grained sandstone, or from some of the beds of the oolite, as, for instance, from the roach beds of the Portland stone. Next to this kind of material is, in quality for concrete, burnt ballast—that is, clay or shale burnt in heaps after the manner of burning bricks in clamps, where alternate layers of material and fuel are disposed so as to indurate the clay, and then broken up into small pieces. The reason why these are the best materials for concrete is, that they are angular, and when deposited in a mass their angles interlock with each other, and make the mass more solid and inseparable than can be had with gravel consisting of rounded pebbles. To make good concrete with gravel it should be large and clean in the first instance, and the larger pebbles broken so as to form as many angles as possible. It is true that very good concrete is made with Thames ballast, which is a natural deposit of gravel, fine gravel, and sand, when Portland cement is mixed with it; but this is due to the excellence of the cement, and Portland cement has been brought to such a great excellence since so much of it was required for the metropolitan main drainage, that it, and not the chief component, is relied upon for the excellence of the cement concrete. When of good quality it adheres strongly to anything clean; but neither it nor lime will make good concrete if the gravel or other material be dirty. There is some difference, however, even in clean gravel; that which is the least rounded is the best. All concrete, wherever used, should be made with either Portland cement or hydraulic lime. The rich lime, very useful for common work, is not good for concrete, for it does not set under water, and in foundations, although water may be in many cases excluded as much as possible by drainage, yet there is always moisture, and common lime requires a free and long exposure to the atmosphere before it will set. Moreover, it will not set without an admixture of a large quantity of sand, and this is detrimental to the concrete.

CONCRETE.

In making concrete, some people say, mix as much sand or fine gravel with the broken stone or gravel as will fill up the interstices, and thus make a solid mass; but we have to consider that when this is done the lime or cement aggregates itself about the smaller particles, and leaves the larger stones comparatively bare; so that concrete thus made has little or no more cohesion than a body of gravel that is naturally deposited, for except in the case of sea-coast shingle, which is a distinct substance from ordinary gravel, nature has already filled up all the interstices of the gravel pebbles with sand and finer gravel. Now, however admirable may be the operations of nature in this respect, we aim at something better for our purposes in making concrete, which is essentially an artificial substance. We have, then, to consider this, whether by the addition of lime or cement to the chief component of concrete we shall make it better by filling up the interstices of the larger particles with concreted sand and fine gravel, or whether we shall, by excluding small particles as much as possible, make the lime or cement stick together the larger particles. To determine this question, we must take into consideration how much lime or cement is allowed to be used. If it is allowed *ad libitum*, we should make the very best concrete by adding to the clean gravel just so much fine material as to fill all the interstices, and the result would then be that the larger particles and the smaller would all be cemented together into a conglomerate rock, for the excess of lime or cement more than is taken up by the fine material then attaches itself to the larger stones; but as economy must be considered, the quantity of lime or cement is limited to some given proportion between it and the chief component. It is seldom that more than 1 of lime to 6 of gravel or broken stone is used, by measure, and more often 1 to 7; and as there are 21 bushels in a cu-

bic yard, every cubic yard of gravel or broken stone requires, with this proportion, 3 bushels of lime. At first sight it would seem strange that there should exist any difference of opinion about the best method of making and depositing concrete, and yet there is such a difference. Some people say, tip it into the foundation from a height —say 10 ft., but do not meddle with it afterwards; while others say, wheel it in and deposit it quietly, and ram it; but this difference of practice may be accounted for and explained by the following considerations: If fine material is mixed with the coarser and they be thrown down together from a height, with the intention of consolidating the mass, the larger material becomes separated from the smaller while falling, and the concrete is found to be in some places an aggregation of large particles and in others of small particles, the separation being due to the difference in the specific gravity of the materials, and the mass, being then less homogeneous, is of course less strong; for the strength of concrete, like that of any other material upon which weights are laid, depends upon its frictional stability, and if the particles of which it is composed are so disposed that they readily slide upon each other, there will be little or no stability. A mass of clean shingle will not carry much weight, for, however hard the individual particles may be, they slide upon each other laterally, and allow the weight to sink. If these are cemented together, the mass will carry a greater weight by reason of the attachment of the cement, and to the degree of its strength. If now, in addition to the attachment of the shingle by means of cement, the interstices were filled, without being over-filled, with finer material, as sand or fine gravel, the strength would be still more increased, because this filling up of the intersects would oppose another obstacle to the sliding of the pebbles upon each other; but that which makes this attempted filling of the interstices practically useless and unattainable is, that it cannot be equally and uniformly insured throughout the mass, the mass consisting in some places of aggregations of large particles and in others of smaller. Now, if this reasoning be correct, it follows that the concrete will be stronger if the finer material be excluded, and, further, that the best concrete is that which consists of angular stones which interlock with each other. Here, then, is to be found the explanation of the difference in practice, when in one case the material is tipped from a height and in another is deposited quietly, for with angular materials of an even size and specific gravity, the greater the height from which they are thrown in, the greater the consolidation will be, while in the other case the less the height the better. In mixing concrete composed of angular stones alone each one is surrounded with its due quantity of lime or cement, which adheres to it during its descent, but if inadherent sand or fine gravel be mixed with it, not only will a separation of the proper relative positions of the materials take place in their descent, but the larger particles will be robbed of their due quantity of lime or cement by the smaller.

It is to be remarked, however, that, even with angular stones, where the concrete is thrown in from a height, the lime or cement will in some degree be shaken off the stones, and although, if we could deposit the mass in very thin and even layers, that which might be separated from one barrowful would attach itself to one below it, and so a compensatory action take place, yet we cannot, or at least do not in practice, spread out the layers sufficiently thin to cause this to take effect. The consideration, then, is whether in any case concrete should be thrown into a foundation from a height, or whether it should not rather be wheeled in upon the level, and deposited as quietly as possible. If it could then be rolled with heavy rollers, the best concrete would probably in that way be made, but as in most cases this could not be done, punning is sometimes recommended to effect a similar purpose. Now, as to punning, there are two considerations belonging to it. Lime or cement deposited dry—that is, not absolutely in water—should not be disturbed after it has once begun to set. If a broad and heavy roller could be drawn over each layer as soon as it is deposited, the consolidation might be effected, or if broad stampers could be substituted the same might be done; but with small punners or rammers it is probable that the action of each petty blow is merely to shift the material laterally, and to still further separate the coating of lime or cement from the stones without effecting a real consolidation.

So far as this lateral movement presses out the material more closely to the sides by which it is confined, whether that be sheet piling, or the sides of a trench or of a foundation pit, it is good for that reason, as it

tends to prevent further spreading of the concrete when the weight of the superstructure and its load is laid upon it. The question, then, is whether a mass of angular stones, which interlock with each other, spread in thin layers and punned so as to press it firmly against the sides, or else tipped from a considerable height, is not more unyielding than a mixture of large and small particles imperfectly cemented together with lime or cement, and either punned or thrown from a height.

That in the London district, where plenty of clean ballast, or coarse and fine gravel and sand naturally mixed, is used with a due proportion of good Portland cement, or with ground blue lias lime, most excellent concrete is made, there can be no doubt; but its excellence would appear to be due wholly to the goodness of the cement, and good Portland cement is not procurable everywhere and by everybody who may use concrete, and if it were, and if a due proportion of it were allowed, clean gravel is not to be had everywhere; but granting that all these are procurable, and allowed in due proportion, the mixing is often so clumsily done as to make null and of no effect the best materials. In short, from these considerations it would appear that a closely packed bed of angular stones is a better foundation than one of weak concrete.

If this be true of dry foundations it must be more true of those deposited in water. When ground lime or Portland cement is mixed with ballast and thrown into water, even though it be but a few inches in depth, and though it be quiet, the best part of the lime or cement—that is, the silicates—will be washed out and form a skin on the surface of the water, leaving the gravel bare. There are many devices to prevent this, such as lowering the concrete down in bags and emptying them at the bottom, shooting the materials down wooden trunks, etc.; and the difficulty of retaining the cement in the concrete when water is present induced Mr. Kinipple to adopt a method which is directly opposed to one of the principles that it has always been thought necessary to observe in dealing with cement, that, namely, that it begins to set as soon as it is mixed, and therefore that its crystallization ought not to be interfered with by working up again cement that has become partially set. But in the discussion on Mr. Grant's paper on the strength of cement, read at the Institution of Civil Engineers, Mr. Kinipple described his method to be to mix the materials on the top with just sufficient water, and to turn them over and spread them out in a thin layer, and when, in a few hours' time, they have become a stiff but not dry mass, to break it up and deposit it in the foundation in a crumbling state, by which means he was able to retain all, or nearly all the cement, in the mass of concrete. But when it becomes expedient to throw overboard a recognized principle in order to accomplish any given end, it may well be supposed that there is something wrong somewhere, and that which is probably wrong in this case, is that the cement was not finely ground, and not thoroughly air-slacked before use, whereby a reserved power of cohesion would ensue, which would be brought into action when the material was broken up and redeposited in water.

PILING.

When foundations are to be laid in ground that contains much water, that is to say, ground that cannot be permanently drained, and when the ground itself consists of fine particles, as silt, sand, or soft clay, the whole mass is more or less fluid, and bearing piles are put down to support the structure. If the ground consists of moderately stiff clay, but which is judged to be not stiff enough for a concrete foundation, its stiffness may be increased by driving short piles in it, whereby it becomes compressed laterally and consolidated. In this case a row of sheet piling should first be driven so as to enclose the whole area to be built upon, and to confine the clay, or the same effect may be produced by driving the outer rows of piles first and working inwards towards the centre; but in adopting this form of foundation it is necessary to proceed with caution, for clay is compressible by weights, but sand is not so, and as silt often consists of a mixture of the two, its compressibility depends on the degree in which it is clayey. In ground containing a large proportion of sand, this kind of foundation is not suitable, for when piles are driven into it it is merely shifted, and not consolidated, rising up between the piles if it cannot escape laterally. On this account some people condemn this kind of foundation *in toto* without reason.

When the immediate ground consists of a soft mass underlaid by a hard stratum sufficient to carry the weight of the structure, and within reach of bearing poles of moderate length, they are, when they consist of

timber, driven through the soft ground, and rest on, or are driven slightly into, the hard ground. They then act as pillars, and, as the ground through which they are driven is not sufficiently stiff to afford them lateral support, they are not capable of carrying much weight, because of their tendency to bend, after the manner of all long pillars. The strongest timber pile foundation is, probably, that in which the ground is moderately stiff or moderately hard, and of considerable depth, allowing long piles to be driven into it, but requiring considerable force to drive them, their bearing power consisting chiefly of the friction between them and the ground, and only partially on that which is due to the area of the base of the pile. In this case they do not act as pillars.

Whichever kind of timber-pile foundation may be adopted, the heads of the piles are cut off to a uniform level, and, if these are below ground, the earth between the rows of piles that has been trodden up by the workmen is removed to a depth of (say) 2 ft. below the heads of the piles, and the space filled in with concrete. The heads of the piles are confined together by cap sills laid across them, and across the sills thick planking is laid down, and the foundations of the structure commenced upon that. This is often the practice in heavy works in England; but in Holland, where the ground consists almost wholly of silt and peat of great depth, the foundations of the houses and other structures are laid upon piles over which fascines are spread, and the ground there is so soft that it would hardly be an exaggeration to say that the houses float upon a sea of mud; and yet they stand eminently well. But to suppose, as has been supposed, that the houses in the towns of Holland stand well because of the excellence of their foundations would be an error, for their stability depends chiefly on the excellence of the brickwork of which they are built; the bricks being very small, compared with English bricks, and very hard. These small bricks being put together with good mortar, and very carefully laid, resist any tendency to settlement in parts of a building, by reason of the tenacity of the mass of brickwork. The bricks are about the same length and the same width as English bricks, but they are not more than 2 in. thick, and often less. The custom in Holland is to drive—but there they do not require much driving—piles of larch or fir trees with the bark on and with the small end downwards, the diameter of the small end being about 6 in. and that of the top about 12 in. These are not driven down to any hard stratum of ground, but depend for their unyieldingness on the friction between their sides and the ground. The top platform of fascines completes the security that may be wanting in any particular pile. For the same reason we spread a layer of concrete between the pile-heads, and further secure the foundation by laying down a timber platform upon the piles, whereby the weight of the heavier parts of a structure is spread over the whole foundation. For durability beech and elm are preferred for piles that are not wholly buried, for when timber is exposed to alternations of dryness and wetness, as pile heads sometimes are, the decay of other sorts is in those parts more rapid; but it is difficult to procure either beech or English elm parallel and of a sufficient length for long piles, and then Baltic fir is mostly used, which can be more easily procured long, straight, and parallel, and, as far as is known, it will last as long as any other timber when wholly buried. American rock elm is also an excellent timber for piles, being straight and very sound, and it will bear more driving than fir.

The dead weight that piles will carry is very difficult of calculation. In forcing them into the ground we use the impact of a weight falling from a height, and the force of that blow we ascertain from the laws of dynamics, the weight multiplied into its velocity at the moment of striking the pile being the intensity of the pressure upon it at that moment; but this is an essentially different kind of pressure to that of a statical or dead weight, and there is no exact means of comparing the two kinds of force. To form any just comparison between the effect of a blow of a ram on a pile head and the dead weight it will carry, we have to experiment from time to time by driving a pile, and noting exactly the extent of its motion under given circumstances of weight and velocity of the ram, and then by driving a similar pile in exactly similar ground, and weighting it with a dead load; and to arrive at anything like accuracy of results, this experiment must be made under each varying condition of size of pile, its weight, load, kind of ground, and manner in which the blows are given; and the latter condition is very important to be consid-

ered in all cases where the resistance of the pile to its load depends upon the friction between its sides and the ground with which they are in contact. To drive a pile quickly, and with the least possible force, its vibration must not be allowed to cease during the operation. The blows should, therefore, succeed each other rapidly, as they do in Nasmyth's pile-driving machine, which gives about 60 blows in a minute, and, in fact, hurries the pile down, while with a crab engine only 1 or 2 blows are usually given in a minute. The jarring produced by the blow on the pile is communicated to the ground in contact with it, and thus the ground is prevented during the time of driving from settling itself about the pile. The friction between the two substances is therefore reduced. But with blows given at long intervals, the ground settles itself about the pile after each blow, and the resistance of friction has to be overcome again. Thus the manner in which the pile is driven is important to be taken into account when estimating from the effect of impact what the resistance to a dead weight would be.

The velocity with which the ram strikes the head of the pile is that due to the fall of a heavy body, less the friction of the guides or leaders, which, for great falls, is considerable. Taking moderate falls, and neglecting this resistance and that of the atmosphere, the velocity is proportional to the square root of the height, and if the height be taken in feet, and the velocity in feet per second, it is 8 times the square root of that height; thus, if the fall of the ram be 16 ft., its velocity at the moment before striking the pile would be $\sqrt{16}$ ft. $\times$ 8 ft.= 32 ft. per sec. If the weight of the ram were 1 ton, the momentum of the blow would be 32 tons, or if the weight be 10 cwt., the momentum would be 16 tons. There can be no doubt that the proper, and indeed only way to find the momentum of the ram at the moment of striking the pile is to multiply its weight into its velocity, as indicated above; but it does not follow that this is the true measure of the effect of the blow, and it is more likely that it is to be estimated by the work done by the weight in falling from a given height, thus 1 ton falling 16ft. is a force of 16 foot-tons, or 10 cwt. falling 32 ft. equally 16 foot-tons; both methods are measures of the dynamical effect, and neither is any proper measure of the dead load the pile will carry.

The great variation in the results of formulæ for calculating the weight that a pile will safely carry seems to be due to the different manner in which investigators regard the effect produced by a ram descending from a height by the force of gravity, in comparison with the dead weight that the pile will carry when driven to a given distance by a blow of a given force. Experimenters on the strength of materials that can be subjected to such strains as are within our power to exert on small specimens, have arrived at tolerably equal results in most cases; but the case is very different when we try to ascertain the power of the ground to hold piles so tightly as to bear given weights by its pressure against given areas of their sides. For this reason it is desirable, as every engineer says, that those who are engaged in pile-driving, whether they be resident engineers, contractors, inspectors of works, or foremen, should particularly note down every action, such as the number of blows actually given to each pile, the penetration or set at each blow, or in any given small number of blows the weight of the ram and the height of its fall, the interval of time between two blows, the nature of the ground, and, indeed, every other circumstance affecting the work done. An investigator into the laws of pile-bearing will then be able, by taking a great number of such notes, to deduce from them formulæ by which the bearing power of piles in other cases, and under circumstances stated, may be calculated. The following is an instance of such observations. The foundations of the abutments of a bridge are laid upon piles pitched 3 ft. apart lengthwise and crosswise, from centre to centre of the piles. They are of Baltic fir, from 11 in. to 13 in. square, and average 12 in. square. They are 22 ft. long, and are driven 20 ft. into silty clay, with occasional thin layers of sand. The weight of the ram was 15 cwt., and the fall 12 ft. The observations made on the driving of the whole number of piles show that, on the average, the first blow with the 12 ft. fall drove down the pile 8 in.; the tenth blow, 4 in.; each blow being given in an average time of 35 sec. These 10 blows drove down the pile 5 ft., being an average penetration of 6 in. each blow. The next 5 ft. of driving required 23 blows, the last of which effected a penetration of 2 in. The time occupied was 12 min.; average penetration per blow 3 in. The third 5 ft. required 40 blows of the ram, the last of which

caused a penetration or set of 1 in. The time was 23 min.; the average penetration per blow 1½ in. The last 5 ft. required 82 blows, which were given in 45 min., and caused an average set of ¾ in., the last blow giving a set of ¼ in. A final blow being given, and the movement showing no increase, the pile was considered sufficiently driven. It was intended that the maximum load on each pile should be 20 tons. A few of the piles were subjected to actual trial by loading each one with 60 tons of iron, and no movement was perceptible. The specified minimum set of ¼ in. with a ram weighing 15 cwt. and falling 12 ft., was in some of the piles attained, while there remained several feet of the head of the pile out of the ground. In these cases two test blows instead of one were given, and on the refusal of the pile to be driven beyond the limit in either case the driving was discontinued rather than run the risk of shaking and damaging the timber, for in these cases it was probable that the point of the pile had met with some partial aggregation of hard material, and to continue hammering the pile head was to expend the force in bruising the timber.

After the heads of the piles had been cut to a uniform level, the ground was excavated to a depth of 2 ft. below them, and the spaces filled in with concrete; sills, 12, in. × 9 in., were notched down upon the heads of the piles, crosswise of the abutment, and upon the sills, sleepers 12 in. by 9 in. were laid over the lines of piles lengthwise of the abutment; the whole area of the foundation was thus bound together, and any unequal pressure on parts of it would be almost necessarily transferred to the whole area. There is an actual pressure on this foundation of two tons per sq. ft., or about 18 tons on each pile, if we consider the piles individually, but if we grant that the whole number are suficiently tied together by the sills and sleepers so as to act as one, then by taking the outside piles as carrying a load equal to that of those inside, the average weight on each is reduced to 15 tons. These abutments are of brickwork, which was begun upon the concrete at the level of the pile heads, thus the spaces between the sills are filled up with brickwork in this case; but it is to be remarked that the spaces are often filled up with concrete, and that the whole area is sometimes planked over and the brickwork begun upon that. In each of these abutments there is a mass of brickwork of about 6,000 cubic ft. interposed between the concussive force of a passing load and the foundation piles, which materially lessens the effect upon them of the impactive force of a live load; but this is a different sort of case from one in which the intermediate structure of a bridge, between its load and its foundation, is of rigid materials and not massive. When the intermediate structure consists of piles of timber or iron, the concussion of a passing load is much more directly transmitted to the foundation. When it is ascertained by any formula what load a pile will carry, whether or not its weight and the measure of its elasticity be taken into account, its actual load should not exceed one-third of the ultimate load where a large mass of material intervenes between it and the pile; and when the load is conveyed directly upon the pile, perhaps one-tenth is as much as would be safe. Major Sanders, of the United States Engineers, has given in the "Journal of the Franklin Institute" a rule which takes no account of the weight of the pile or its elasticity, its length or its sectional area, and which, therefore, seems to be a rule which leaves important elements out of consideration. It is this:—"The pile will safely bear, without danger of further subsidence, as many times the weight of the ram as the distance which the pile is sunk; the last blow is contained in the distance which the ram falls in making that blow, divided by eight," provided the pile moves equally at several of the last blows. To apply this to the case above mentioned, in which the weight of the ram is 15 cwt., the fall 12 ft., and the last set ¼ in., the ratio between the fall and the set is as 576 to 1,

$$\text{and } \frac{576 \times 15}{8} = 1080 \text{ cwt.} = 54 \text{ tons.}$$

The same rule is fomulated in Molesworth's "Pocket-book" thus:—

Let D = the set of the pile by the last blow, in inches.
Let H = height the ram has fallen, in inches.
Let L = safe load for the pile in cwts.

$$\text{Then } L = \frac{W\,H}{8\,D} \text{ approximately.}$$

He adds that W, the weight of the ram, is 4 cwt. in ordinary pile engines, which we can hardly understand, and attribute it to an error of the printer. Taking W, however, to represent what we believe to be the ordinary weight of the ram of a crab pile engine—viz., from 10 to 20 cwt., and in the

case now under notice actually 15 cwt., the formula may be applied thus :—

$$D = \tfrac{1}{4} \text{ in.}$$
$$H = 12 \text{ ft.} = 144 \text{ in.}$$
$$W = 15 \text{ cwt.}$$

Then let $L = \frac{W\,H}{8\,D} = \frac{15 \times 144}{8 \times \frac{1}{4}} = 1080$ cwt. $= 54$ tons as before.

Professor Rankine, in his "Manual of Civil Engineering," says that for piles standing in soft ground by friction (as in this case) it appears from practical examples that the limit of the safe load is about 200 lbs. per square inch of area of head. This would be about 13 tons on one of these piles. But in an elaborate formula which he gives for the ultimate or greatest possible load, in which not only the conditions above stated are taken into account, but the sectional area of the pile, its length, and the modulus of its elasticity, that ultimate load would be, according to this formula, about 220 tons, so that the 54 tons derived from the formula of Major Sanders and Mr. Molesworth, as a safe load is about one-fourth of the greatest possible load; the 18 tons previously mentioned as the possible actual load on one pile in these foundations is one-twelfth; the more probable actual load of 15 tons is one-fifteenth; and the 13 tons derived from Mr. Rankine's statement of 200 lbs. per square inch of head is one-seventeenth of the greatest possible load according to his own formula.

It does not appear that any of these authorities have taken into consideration the manner in which the piles are to be driven in respect of speed; but that must surely influence the result very much; for if a pile be run down so rapidly that the vibrations are communicated to the ground in contact with it at the moment of giving the last blow, a certain penetration or set of (say) $\frac{1}{4}$ in., due to that blow, would indicate a greater bearing power in the pile than the same set if the blow were given to the pile after the ground around it had had time to come to rest. In the former case we might expect a small set, such as $\frac{1}{4}$ in., to indicate that if, after it had been given, the pile were to be left untouched for a minute or so, and another blow then given of the same intensity as that which drove it the last quarter of an inch, it would be immovable.

LOCOMOTIVE WORKING EXPENDITURE.

From "The Engineer."

The comparative table given this week on another page refers to the cost of working and maintaining the locomotive engines on 25 of the leading railways of the kingdom. The figures are taken from the official reports of the companies for the latter half of 1871, and are arranged and analyzed so that the calculations based upon them may admit of the most perfect comparison in every detailed item between any of the companies whose position, and the nature of whose traffics, would allow of comparison. It will be observed that, in addition to the cost of running and maintaining each company's own engines, any special and extraordinary items of expenditure, and the haulage performed either by or for other companies, are added; and, in the result, we arrive at the net cost which has been incurred in moving the traffic on each of the companies' lines independently. The necessity of thus including the work done on any particular line by the engines of another company is exemplified in the London, Chatham, and Dover, and Manchester, Sheffield, and Lincolnshire companies. On the former the engines of other companies performed work for which the owning companies were allowed no less than £6,256, or about 12 per cent. of the net cost of the Chatham Company's locomotive power; and in the case of the Manchester, Sheffield, and Lincolnshire, it appears from the accounts that between 30 and 40 per cent. of the working cost of their engines is incurred on other lines which that company operates or works over. By means of the totals of all the different companies' figures together, we are enabled to arrive at certain averages which are invaluable as showing what may be taken as the mean, in every item of expenditure, of all the railways in the kingdom. Indeed, the smaller independent lines not embraced in the table form altogether a mere tithe of the whole, and their being brought in would not in any way materially affect the averages we are able to give.

Before proceeding to give a few of the chief features as recorded in the table, it will be as well to direct attention to certain

points, and also to certain assumptions which we have had to adopt in order to insure exact uniformity in each of the companies' figures. In all cases the number of engines is the total stock of the company, effective and non-effective, and includes the tender as a part of each engine. The railway earnings include only what has been earned by the trains on each company's own lines; and the train mileage is what is run by each company's stock, but is exclusive of ballasting, shunting, and piloting, which the majority of the companies do not give in their reports. The "ordinary working expenditure" includes superintendence, running expenses, and the ordinary repairs and renewals of each company's locomotive plant. All such items as outlay on premises, turn-tables, and new stock acquired at cost of revenue, are included with the extraordinary expenditure; as also is the haulage, other than that necessary in moving the traffic on each company's own lines, that done for other companies being a deduction, and that performed by other companies being an addition to the expenses of each company's own locomotives. In many cases the haulage done for other companies is not distinguished in the accounts, being included with the gross amount received as "remuneration for working other lines." In all such cases it is assumed that haulage by engines forms the same proportion of this gross amount as the company's own locomotive power bears to the total of their own working expenses. The haulage done by other companies is the actual amount paid to or retained by them for work done on another line, and might not therefore be the actual cost (but a close approximation) to the owning company of the work performed. Generally 20 per cent. of the receipts is allowed by the companies for haulage on another line, but 12 per cent. ought, as shown in the table, to cover the locomotive power in such cases, and about 3 per cent. for the other plant, making 15 per cent. in all. In the Caledonian Company's accounts there appears an item of £13,220 as "provision for future renewals," which we have included as "extraordinary," not being actually laid out in the half-year dealt with. The Great Eastern Company show an outlay of £21,676 "for new engines purchased," which is also included as special. The Brighton Company built five engines and two tenders, which, after allowing for the value of a like number broken up, cost £10,340; and, although the item is specially included in the company's accounts, we treat the sum as ordinary renewals. The expenses of working the joint lines belonging to the Metropolitan and Metropolitan District Companies, not classified in the accounts, are apportioned in each case to locomotive power in the same ratios as the total working expenses are of the portion which is classified. It may also be stated that the amounts appearing in several of the companies' accounts as power supplied to contractors, and to the engineers' department, etc., are treated precisely as if supplied to other companies.

The first means which the table affords for comparing the ordinary working expenditure is in the average cost "per engine." A great disparity exists in the number of engines possessed by the different companies, when taken in connection with the length of line, weight of traffic, etc.; and on some lines the amount of work done by each engine greatly differs, making, therefore, a comparison in this way somewhat misleading. As, however, we propose in a subsequent table to show the numbers, cost, mileage run, and earnings, and working cost taken together, we shall merely at present point out how variable the expenditure is *prima facie* by this method of comparison. It should be borne in mind, too, that on some lines as many as 10 per cent. of the engines are non-effective, whereas on others few, if any, will be out of order or under repairs. The average per engine of the total ordinary working expenditure is £305 on all the lines taken together. The greatest variations from this average, in both directions, are shown on the Glasgow and South-Western and Metropolitan District. On the former it is only £196 per engine, and on the latter it is £570. These would be extreme cases to adopt for a close comparison of each item constituting the whole expenditure; but it will be observed that the repairs and renewals, although comparatively low on the Glasgow and South-Western, are considerably higher per engine than on the District line, and no less than £224 of the difference is explained by the higher cost of fuel on the latter. This last named item is £53 on the Glasgow and South-Western, against £277 per engine on the District, a difference against the latter of over 400 per cent. The gross expenditure per engine on the Metropolitan, which should be the fittest for comparison with the District line, was £472

per engine only, or 20 per cent. less. Taking several of the leading lines, somewhat analogous in every other respect, we find some surprising and apparently unaccountable differences. On the North-Eastern the expenditure is £352 per engine; on the Midland it is £319, on the Great Western the average is but £291, and on the London and North-Western it is £241 only. This last average is just 70 per cent. of that shown by the first-named line. The greatly different results cannot be traced to any particular cause, the same remarkable anomalies existing both in the "running expenses," and in the "repairs and renewals." It will be noticed that, next after the Metropolitan lines, the southern companies' engines cost the most to run, and the fuel, owing to the distance which it has to be conveyed, accounts for the greater part of the increased expense on these lines. Repairs and renewals average £107 on all the 25 lines together, the item varying from £39 on the District to £149 on the London and South-Western. Next after the latter, the Great Southern and Western (Ireland) and the North-Eastern Companies have been most liberal in this respect. The various items which go to make up the total working expenses of our locomotives, as exhibited in the averages shown in the table, are for a half-year :—

	Per engine.	
		£
Salaries and superintendence		7
Running expenses :		
Wages	92	
Fuel	77	
Water	6	
Oil and tallow	16	
		191
Repairs and renewals :		
Wages	55	
Materials	52	
		107
		305

The next means of comparison afforded is that shown in the average per train mile. This method is more perfect than the former in this respect, that it allows for the work actually done by the engines on the various lines; and, so far as the running expenses are concerned, we could not find a more desirable way of judging of the merits of each case. In this way the gross working expenditure amounts to 7.80d. per train mile as the mean on all the 25 lines. If we take companies whose earnings are chiefly derived from a fast passenger service, we find their averages per mile are somewhat the same as those whose traffic is of a slower and heavier nature. Leaving out the Taff Vale lines, the engines of which are about as much employed in shunting and arranging their short mineral traffic as in actual running, it will be observed the highest average is shown by the London, Chatham, and Dover, and the lowest by the Great North of Scotland, the former being 9.92d. and the latter 5.59d. only, or 43 per cent. less. The great difference between these two cases is traceable in each item constituting the whole working expenditure. Some of the leading lines present remarkably uniform averages in the cost per train mile. On the Lancashire and Yorkshire it is 7.53d., on the Midland 7.49d., on the Great Northern 7.45d., and on the North-Western 7.44d. The mean average cost connected with the actual running of the engines is 4.89d. per train mile on all the lines, being in the proportion 2.36d. for wages, 1.96d. for fuel, and 0.57d. for water, oil, tallow, etc. The company showing the highest average is the Metropolitan District with 7.85d., and the North British the lowest, being 3.92d. only, or exactly one-half the former. By this way of comparison the London and South-Western, it will be observed, are not in the first position in the matter of repairs and renewals to their locomotives, as they appeared when comparing the average outlay "per engine." The Great Southern and Western leads with 3.65d., and the North-Eastern and Sheffield have also been liberal as regards repairs. The stock of the District Company being entirely new, as might be expected the outlay upon it has been extremely small; but surely that of the Metropolitan Company was entitled to receive somewhat more than the 13.8d. per mile actually expended. Taking the various items as recorded by this method, it will be seen that the outlay, as shown in the mean of all the lines, is made up as follows :—

	Per train mile.	
		d.
Salaries and superintendence		.17
Running expenses :	d.	
Wages	2 36	
Fuel	1.96	
Water	.16	
Oil and tallow	.41	
		4.89
Repairs and renewals :		
Wages	1.42	
Materials	1 32	
		2 74
		7.80

The third means of comparison is the same in its results as the first, but stated in a somewhat different form. It may for our purpose be assumed that the average cost of a locomotive (taking them with and without tenders) is £2,000; and on this basis we arrive at the "lifetime," or period within which the outlay on repairs and renewals will have equalled the prime cost. Of course the company showing the smallest number of years is ostensibly the one dealing most liberally with its stock. The mean average recorded in the table is 9¼ years on all the lines, and varies from 6¾ to 25½ years, although this latter average, being that of the District line, is altogether exceptional from the cause already explained.

The last comparison, and the one most generally adopted, is by taking the percentage which the net cost of locomotive power forms of the gross earnings. The mean of all the lines is 12 per cent. The South-Eastern Company's percentage is the lowest, viz. 9.8, and the Metropolitan District the highest, viz., 18.8 per cent. When the latter company's engines, as they must shortly do, begin to need the usual and ordinary repairs the difference between these two will be still greater. The Caledonian, North London, and London, Chatham, and Dover averages are each of them extremely high. The percentages which the various items composing the net locomotive power of the different lines form of the gross receipts, and the relationship which each item bears to the total expenditure of the department, may be summarized as follows:—

	Of gross receipts.	Of total loco. power.
	%	%
Salaries and superintendence.	3	2.2
Running expenses:		
Wages	3.7	30.9
Fuel	3.1	25.6
Water	.3	2 1
Oil, tallow, etc.	6	5.5
	7.7	64 1
Repairs and renewals:		
Wages	2 2	18.6
Materials	2.1	17.2
	4 3	35.8
Sundries	less .3	less 2 1
Total	12.0	100.0

Taken altogether the present table will be referred to with very great interest by a large number of our readers; and the various data, which the mean averages therein given afford, will be of much service in the guidance of those who are without the valuable assistance which the figures in the reports of the companies would give them.

In a subsequent table we purpose giving similar statistical information in respect to the working of the carriage and wagon department on the different lines.

PUDDLED WALLS.

From "The Engineer."

Until the introduction of asphalt, the particular description of clay known technically as "puddle" was the material relied upon to render the crowns of arches and the backs of retaining walls secure against the infiltration of water. Concrete now is constantly employed in a somewhat similar manner for the latter of these purposes; but, in addition to acting merely as a water-tight agent, it performs the additional duty of adding to the strength and stability of whatever portion of a wall or building it may be applied to. There is no question that the concrete backing of a retaining wall forms an integral part of the whole structure, and could not be removed without putting in peril the stability of the remainder. Puddle, in the strict acceptation of the term, was never used in this manner. It is true that, incidentally, a puddle core may occasionally increase the strength of a dam, the embankment of a reservoir, or reclamation wall; but no reliance is ever placed upon such adventitious assistance. Without the piles and waling pieces in the first instance, and without the inside and outside slopes in the second and third, the puddle core would be valueless. While supported by the slopes, the duty of the puddle is to prevent the water finding its way into and under the whole mass, which would impair its resisting powers, and ultimately destroy the dam altogether. The necessity for insuring that the puddle accomplishes this important duty is obvious. Hence the great care displayed by engineers in drawing up the clauses in specifications relating to the quality of this material and the manner in which its employment is to be carried out. But it is in the actual making of a puddle

wall that constant supervision and attention are so requisite, not only on account of the danger that may arise from any neglect or remissness, but on account of the serious expenses that must frequently be incurred before the evil can be remedied. The construction of a good puddle wall is one of the few operations which must be accomplished slowly and laboriously. It cannot be hurried. Layer after layer, rarely exceeding 1 ft. in thickness, must be piled up with regularity, and the whole mass, by degrees, thoroughly incorporated in a tedious and mechanical manner, that would prove very monotonous to any but unskilled workmen. Confining our attention to that description of puddle wall which usually occupies the central position in the embankment of a water reservoir, it must be admitted that our examples bear no comparison with those of foreign countries, either in magnitude or excellence of construction. If we take India, for instance, not in the condition it is at present, but as it was in the days of the Abdallahs, and Aurungzebes, we shall find that the inhabitants in those times possessed a perfect knowledge of the art of building puddle walls. Many of their reservoirs remain comparatively intact at present, and by their size and mode of construction bear witness to the skill of those who designed and erected them. Even now the natives of India make far better puddle walls than we do. This circumstance may in some measure be due to the peculiar manner in which walls of this kind are made in all Oriental countries, in which the people make no use whatever of barrows, and are altogether ignorant of the advantages of "plan." It is also possible that the making of a puddle wall is just the style of work which suits the patient and indolent disposition of the Eastern workmen.

It is in this case of reservoir embankments that the largest puddle walls are used, and the question of the relative position with regard to the rest of the bank in which the puddle should be placed, has been frequently discussed by engineers. It formed a prominent point in the inquiry that was carried on with respect to the bursting of the great Sheffield embankment about ten years ago. As a rule, puddle in our reservoir banks is employed as a trench and as a wall, but only in both of these situations as a water-tight agent. These two in reality constitute but one, since the trench is nothing more than a foundation for the puddle wall, and is part and parcel of it. Sometimes, as to other foundations, there is more trench below the ground than wall above it; and in one well-known instance the trench was carried down to a depth of 120 ft. with a head of water of nearly 100 ft. This is an extreme case, and although time has shown that it may be imitated, yet it would be prudent to avoid imitation where possible. There is a great difference of opinion among engineers on the question of the height to which reservoir banks may be carried with safety. No less an authority than the chief engineer of the Ponts et Chaussées asserts that when banks of this description attain a height of between 60 ft. and 70 ft. their stability is a mere matter of chance. As there are many banks considerably higher than this, it is difficult to believe that the security of all of them is so precarious a matter. The statement of the engineer of the Ponts et Chaussées must have resulted from a consideration of the practical difficulties of constructing a water-tight embankment. Theoretically speaking, there is no limit to the size of a bank, with or without a puddle wall. If the presence of water be left out of the question and the attacks of vermin, an embankment can only fail, in a constructive sense, by slipping on its base. This contingency can only happen when the cross section of the ground is a tolerably sharp slope, and in that case it is usually guarded against by cutting horizontal steps or benches on the side of the slope.

It is evident that so far as any strength accrues to an embankment from the presence in the centre of it of a puddle wall, that position might equally well be occupied by the same quantity of material of which the rest of the bank is formed. But yet, as the bank must be water-tight as well as stable, the puddle must be placed somewhere in it. Accordingly we find that reservoir and similar banks have been constructed without puddle walls in their centre, but with the puddle laid on their front slope, and protected by stones or other material from the erosive action of the water. In those instances in which this system has been adopted, the puddle trench, where it is necessary to make one, occupies relatively the same position with regard to the puddled slope as it does with regard to the wall in the other method of construction. Instead of being carried longitudinally along the centre of the bank, it runs in the same direction near

the toe of the front slope. There is no doubt but that in this situation the puddle is capable of rendering an embankment thoroughly water-tight. At the same time it is questionable whether it is not more liable to be affected by cracks. It is evident that the puddle in the form of a vertical wall is more disposed to settle, and to become close and dense by virtue of its mere weight alone, than when it is laid along the face of a slope, in which position its own insistent weight has no effect in helping to improve its consistency. On the other hand, from the larger extent of surface, the puddle on the slope affords greater facilities for that thorough incorporation and kneading of the material which is so indispensable in all puddle, whatever position it may occupy. Although it has been stated that the puddle is to be regarded solely as the staunching feature in a bank, yet the central puddle wall or core does add to the stability of the bank, which puddle placed along the slope does not. The former performs a double duty, the latter only a single one. Without laying down any rule respecting these two positions of the puddle in an embankment, it should be stated that the nature of the materials to be obtained for the purpose must exercise a very great influence upon the matter. The reason why the central puddle wall is generally adopted here, is that our materials are not of a very superior description; and, moreover, our method of making puddle is not so perfect as that practised in Eastern countries. A very sound central puddle wall can be made with materials and in a manner which would not be suitable to a puddled slope. The latter requires the best material and the best method of putting it together. This method is certainly that used by the natives of India, and consists in basket labor and "padding over." As good material for puddle can, as a rule, be obtained in India, it is not, therefore, surprising to find that in some of the most recent canal embankments the puddle has been placed in the slope instead of in the centre of the bank. There is one little detail to be borne in mind in putting the puddle along the slope. It relates to the layer of earth immediately underneath the puddle, which should be of a firm but not of too solid a description. It should be well pressed or rammed, and brought to an even surface. If too hard, the puddle will in settling open and crack. The two layers, the puddle, and that upon which it rests, should settle together, and it is in the proper insuring of this that the success of the bank will mainly consist.

Among the arguments bearing against the principle of placing the puddle in the slope of a bank are, that more puddle is required, that it is too near the water, and, in consequence, liable to be affected by the actual impactive force of a wave, instead of by its mere attempt at infiltration, and that, in consequence of being inclined at an angle with the vertical, it would be more liable to crack in the event of settlement taking place. The last of these arguments is the one entitled to the greatest consideration. But the danger can be guarded against by taking those precautions which are necessary in all cases of puddle making. Banks have been constructed in India and elsewhere without any distinct puddle wall or slope; but the material consisted of sand or gravel of so exceedingly argillaceous a character, that, combined with the manner in which it was put together, it rendered the whole bank almost one water-tight mass. But for the expense, concrete might in many instances be substituted for the puddle trench both in the centre of the wall and at the toe of the front slope; and in any case, when it is required to carry the trench down to a very great depth in order to reach a water-tight stratum, it may be advantageously employed, as there would be then no necessity for going so far down. In all probability concrete will in future be more employed in works of this description than formerly, as the many advantages it possesses for the purpose over any other material are sufficient in ordinary cases to more than counterbalance the additional expense its use entails. It is also deserving of consideration whether asphalt in some one or other of its numerous phases might not also be found useful in such works. It must be borne in mind that there is no such thing as a stereotyped method of designing and executing engineering work, although it is true that some of the processes employed do partake very much of that character. Yet, with the incessant progress of science and professional knowledge, and the new applications that are made either of untried materials or of those whose value in construction has been already well established, there is abundance of scope for the ingenuity and skill of the engineer to be displayed without adhering slavishly to any particular pattern or design. First principles must always be strictly attended to, but it is in their various applications that the ability of the professional man is best shown.

Analysis of Pig-iron and of the Purified Cast-iron, Steel, and Iron made from it by Henderson's Patent Process.

DESCRIPTION.	Authority.	Graphitic carbon.	Combined carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Iron, by direct determination.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Bowling, No. 2, pig-iron*	E. Riley	3.155	.581	1.646	.070	.635	1.472	92 654
Wrought-iron from do. do.†	Dr. Noad	....	.272	none	barest trace	none	none	99 500
Barrow, No. 4, pig-iron	Do.	2.750	.450	1.500	.078	.024	.520	99.200
Purified cast-iron from do.	Do.	none	2.13	none	03	none	.27	97.306
Wrought do. do.	Do.	none	.25	none	.02	none	none	99.500
Cast-steel from above wrought-iron	Do.	none	1.21	none	.01	.02	none	
Gartsherrie, No. 4, pig-iron	E. Riley	2.469	.501	1.348	.231	.896	.546	93 898
Purified cast-iron from do.	Do.	none	2.38	.01	04	.08	trace	97 912
Steel from do. do.	Dr. Noad	none	1.53	.09	.05	.04	trace	98 000
Wrought-iron do. do.	Do.	none	31	.05	.02	.05	trace	99.320
Cast-steel from above wrought iron	Do.	none	1.06	none	.01	.04	none	
Clarence, mixed Nos., foundry iron	Do.	2.750	.500	1.920	.037	.840	.900	92.200
Purified cast-iron from do.	Do.	none	2.37	.04	trace	.22	.17	
Wrought-iron do. do.	Do.	none	.14	none	none	.05	none	
Cast-steel from above wrought-iron	Do.	none	1.003	.07	.004	.04	.07	99 160
Clarence, No. 4, foundry pig-iron‖	W. M. Williams	2.790	440	2.333	.005	.91	.75	
Purified cast-iron from do.	Do.	?	2.60	.12?	trace	.18	.55	
Wrought-iron do. do.	Do.	?	.30	.07	trace	.09	.33	
Millom, No 4, forge pig-iron	Do.	2.550	1.280	2.825	.09	.07	trace	
Purified cast-iron from do.	Do.	?	2.97	.15?	.09	.03	trace	
Purified do. do. do.	Do.	?	3 00	.12?	.06	.029	trace	
Do. do. do. do. treated with oxide of manganese, etc.	Do.	?	2.77	.15?	.08	.03	.61	
Steel from above pig-iron	Do.	?	.94	.07	.01	.02	.45	
Linthorpe, No. 4, pig-iron§	Lloyd & Co.	2.70	90	.66	.06	.96	.64	94.08
Iron when to "nature" in furnace from do.¶	Hopkins, Gilkes & Co.	....	1.80	....	.02	.02		
Finished bar-iron from do. do. do.‡	Whitwell & Co.	....	....	.08	barest trace	.04		
Do. do. do. do. do. do.	Dr. Noad	....	....	....	....	.05		
Dalmellington, No. 4, pig-iron	Dr. Noad	2.500	.380	2.350	.016	.600	1.100	92 240
Wrought-iron from do. do.	Do.	....	.34	.04	.01	.03	.08	99.200
Do. do. do. do.	Do.	....	....	....	.01	.02		

* Edward Riley, Esq., F. C. S., London.
† Dr. Henry M. Noad, F. R. S., do.
‖ W. Mattieu Williams, Esq., F. C. S., F. R. A. S., Croydon.
§ Messrs. Lloyd & Co. Middlesborough.
¶ Messrs. Hopkins, Gilkes & Co., do.
‡ Messrs. Whitwel & Co., Stoockton.

Results of Experiments to ascertain the Elastic and Ultimate Tensile Strength, etc., of five Pieces of Steel Bar, received from Messrs. Stones and Campbell.

Test No.	Description.	Stress. Elastic, per sq. in.	Stress. Ultimate, per sq. in.	Ratio of elastic to ultimate.	Contraction of area at fracture.	Stress per square inch of fractured area.	Extension. 100,000 lbs. per square inch.	Extension. Ultimate.	Appearance of fracture.
		lbs.	lbs	per c.	per c.	lbs.	lb.	per c.	
G. 1350	¾ in. sq hammered	73,200 / 68 tons	115,760	60.2	2.5	118,728	1.78	2.4	100 % granular.
1351	Do. do. heated and annealed	60,600	114,220	53.1	4 5	119,602	2 60	3.8	100 % do.
1516	1 in sq. hammered	76,400	126,120	61 6	3.3	130,470	1 48	3.2	100 % do.
1574	Do. do. heated and annealed	50,200	100,280	50 1	14.0	121,206	9.22	9.6	100 % do.
1517	⅞ in. oct. hammered	72,100	120,240	60 0	3.5	124,601	2.0	3 4	100 % do.
1575	De. do. heated and annealed	63,400	115,520	54.9	12.3	133,526	3.58	7 2	100 % do.

The Grove, Southwark street, London, S. E., 16th May, 1873.

(Signed) DAVID KIRKALDY. [Seal.]

No. 1350 was made at Govan Steel Works near Glasgow, from bar-iron made from Clarence pig-iron.
No. 1516 " " " " " " " Barrow "
No. 1517 " " " " " " " Gartsherrie "
Bar-iron all made by Henderson's process.

THE OXYHYDRIC LIGHT.

From "Engineering."

In a recent issue, we mentioned the decision which had been arrived at by the Municipal Council of Paris, based upon the conclusions of the report of M. Louvet, and that permission had been refused to the Tessié du Motay Company to establish mains for the distribution of the oxyhydric light to public and private consumers. Permission had previously been accorded to lay down mains for a distance of 8,000 metres, and M. Félix le Blanc, gas inspector, had been instructed by the Prefect of the Seine to follow, with M. Darcel, engineer-in-chief to the service of gas-lighting, all the trials made at various times with the oxyhydric light, and to complete these trials by the experiments necessary to clear up doubtful points—experiments made in the presence of the representative of M. Tessié du Motay. M. le Blanc has recorded his experiments in a report, which served as a foundation for that of M. Louvet. We have before us both these reports, and although the question of oxyhydric gas has for the present been definitely decided at Paris, it is still being considered elsewhere, and we think it will be found of interest if we explain the manner in which the various experiments were made, and the principal results obtained.

The first invention of M. Tessié du Motay consisted in projecting a mixture of ordinary coal gas and oxygen, not on a pencil of chalk, as in the Drummond light, but on a cylindrical stick of compressed magnesia, or even on a piece of zircon. The light thus obtained is, as is well known, very brilliant, and the discovery made by M. Tessié du Motay of an economical mode of producing the oxygen, led him to think that his new system of illumination presented important advantages. His process of manufacture is based on the employment of manganate of soda, decomposed by a current of superheated steam. This reaction disengages the oxygen at red heat. The soda is then regenerated by the passage of a current of air, which revivifies it by leaving its oxygen behind it. This alternate operation of abstraction and regeneration can be repeated almost indefinitely.

Subsequently the Tessié du Motay Association abandoned the use of refractory pencils, either of magnesia or zircon, made incandescent by the action of the ignited jet of mingled gases, and adopted a new system, which consists of projecting the oxygen in the axis of a flame obtained by the combustion of coal gas, previously charged with the vapor of volatile oils rich in carbon. This effect is produced by means of special burners delivering the hydro-carburetted gas around their circumference, and the oxygen in the centre, the two gases being led to the burners by a separate system of mains and service pipes. The flame thus obtained is very bright if the two gases are blended in the proportion of 1 of hydro-carburetted gas to ½ or a little more than ½ of oxygen by volume.

When authority was granted to M. du Motay and his colleagues to distribute his gas experimentally in Paris, for a distance of 5-8ths of a mile, they did not employ the ordinary gas, but laid down besides the pipes required for the oxygen, a second series, to lead to the burners, rich gas distilled from Boghead coal. This fact, taking into consideration the short distance from the burners to the reservoirs, has led M. le Blanc to remark, in his report, that the company was working under conditions very different to those that would be met with, supposing that a general concession for canalization was conceded to them. The engineers of the company acknowledged themselves that their experiments did not conform with the condition of every-day practice.

A double series of trials were made under the direction of M. le Blanc. 1. In the public streets; and, 2, in the laboratory, and in the dark room of the gas-testing service of Paris. In these experiments the oxygen was burned, 1, with Boghead coal gas; 2, with carburetted coal gas; and, 3, with the ordinary gas of Paris, without any previous carburization. We may speak first of the experiments made in the public streets. They were conducted on the Place du Nouvel Opéra, with two lamps, the first being supplied with the mingled gas, and the second with the ordinary coal gas, and these served to give comparisons of luminous intensity—comparisons made by means of the photometer. At the foot of the first lamp two gas counters were fixed, the one intended to measure the oxygen, the other the coal gas. The consumption in litres of each was thus obtained per burner and per hour. The Oxyhydric Light Company was allowed to attach to each counter a Girard regulator, to obtain for the gases a suitable pressure, and the apparatus, once regulated, remained constant.

The basis of all the calculations determining the results of the experiments, is the price of the oxygen—a price determined by the Society itself. This has been fixed at 0.50 francs the cube metre for the city, and at double that price for private consumption. The reporters consider this price as too low, especially when the cost of carburetting the combustible gas is taken into consideration, and they conclude that only under certain conditions the numerical results deduced from experiments must be accepted, and that certain of these results which appear favorable to the employment of the oxyhydric light, are apparent rather than real.

It must be remembered, also, that one of the data that must be used in making a comparison of price between the oxyhydric and the common coal gas, with equal light, is the price of the latter, which in Paris is 3-10ths of that proposed by the Company for the oxygen for public consumption, and 3-5ths that for private use. In the first series of experiments made on the Place du Nouvel Opéra, with the Boghead coal gas, two kinds of oxyhydric burners were employed—the bat-wing, No. 2, of average consumption, with a short spread-out flame, and a large jet, No. 3, with a long straight flame and of large consumption.

Bat-wing burner, No. 2. With this burner, the average consumption per burner and per hour was:

Boghead coal gas	2 340 cub. ft.
Oxygen	0.998 " "

The photometer indicated an illuminating power of 1.7, the light given by the ordinary gas burner being taken as 1. The total price for the city, per hour and per jet, at the price previously given, will be thus:

Boghead coal gas	2.340 cub. ft.	.663 pence.
Oxygen	0.998 " "	.141 "
Total		.804

With an ordinary jet, burning the common coal gas, and consuming per hour 4.924 cubic ft., the expense is .21 pence. The proportion between the prices is thus $\frac{.804}{.210}$ per jet and per hour. But the lighting power of the oxyhydric gas being 1.7 times

greater than that of the common gas, the proportion of prices, with equal light, will be:

$$\frac{.804}{.210 \times 1.7} = 2.25.$$

The oxyhydric gas used under similar conditions would thus cost the city 2.25 times as much as the ordinary gas.

For private consumers the price of oxygen, as given by the company, being 1 franc instead of .50 franc, and that of the ordinary gas .30 franc instead of .15 franc, the proportion of prices of the two kinds of lighting, the degree of illumination being equal, would be 1.32 instead of 2.25.

The difference in this case is less striking.

With the large burner No. 3 the consumption per jet and per hour was:

	Cubic feet.
Boghead coal gas	3.558
Oxygen	2.580

In proceeding with the computation as before, and allowing for the increased illuminating power, which is 3.3 to 1, it is found that with an equal light the oxyhydric light, with jet No. 3, would cost twice as much to the city as the ordinary coal gas; for private consumption it would be 1.25 times greater.

A second series of experiments was made with the public lamps upon the carburetted coal gas and the oxygen. The Lenoir carburator was employed, and the liquid used was Boghead coal oil, worth about 5½ d. per pound. The average consumption of oil per cube foot of gas was 32.25 grains. Working from the data obtained from these experiments as before, and admitting always the prices fixed by the Company, it is found that the proportion between the prices of the oxyhydric and the ordinary gas, with equal light, is for the city use equal to

$\frac{2.2}{2.3}$ with the large burner No. 3.
$\frac{1.14}{1.30}$ " butterfly jet No. 2.
$\frac{1.13}{0.6}$ with a smaller burner No. 1.

At the conclusion of the experiments made in the streets, the engineers of the Tessié du Motay Company appeared to appreciate the many grave difficulties which lay in the way of its adoption for public use, and turned their attention to making it available for private consumption.

The experiments conducted in the laboratory of the service for testing gas, dealt with many different modes of lighting, several of which have only an indirect bearing on the oxyhydric gas. We need only refer to those made with the Boghead coal gas and oxygen, and with carburetted gas and oxygen.

The former, conducted with different burners, showed, that even with the most advantageous forms of jet, that is to say, with the large burner, No. 3, economical results, with equal illuminating power, could not be obtained. In the trials made with the carburretted gas and the oxygen, the Lévêque carburator was used in accordance with a wish expressed by the engineers of the Company. In this carburator the vertical wicks are immersed at their lower ends in the hydrocarbon, which rises throughout their length by capillary attraction. The gas circulating around the moistened surfaces is charged with the vapors which are given off by the volatilization of the oil.

Experiments were commenced with Boghead oil, of the price of about sixpence a pound. Altough this liquid gives very variable results as regards the illuminating effect produced during the different periods of volatilization, it is preferable in all respects to the preparations of petroleum, which are still more variable.

The jet No. 1 (*bec bougie*), experimented with at first, did not give favorable results. With a jet of the same form, No 2, the proportion of price between oxyhydric and common gas lighting, with equal illumination, and for private consumption, was found equal to $\frac{1.38}{2.55}$. These figures would indicate in this case a marked economy. But this advantage, according to the reporters, is not real, because it is only obtained by powerful carburation, the expense of which does not appear to have been ascertained by the Company.

The same remark is applicable to the results obtained with the large jet, No. 3. This burner was the object of a great number of experiments made under varying conditions with the Lévêque carburator. The rest of the experiments, compared like the preceding ones, showed that it is with the burners of large consumption that the greatest advantage is obtained in regard to the lighting power as compared with the cost of the gas. The lighting power increases much more rapidly than the consumption, showing that the oxyhydric gas does not

give a divisible light, that is that it does not permit of the advantageous employment of small jets of low consumption.

Employing always the prices fixed by the Company in computing the results obtained with the large jet, No. 3, a great economy is arrived at. The reporter concludes that, if the selling prices for the oxygen could be considered trustworthy, and that if it was not necessary to take into account a greater degree of carburation than is provided for by the Company, the oxhydric gas consumed in burners of large consumption could supply light at a lower price per unit than common coal gas.

He observes, however, that the light from these burners is at all times too powerful for private use, and that it has to be reduced by the interposition of ground or enamelled glass, which obscures from 25 to 30 per cent. of the light emitted.

The experiments, conducted by M. le Blanc, appear to have been made with the greatest care. All the doubtful points that required to be investigated, he has examined. It would have been interesting, however, had he experimented upon the action of cold upon the carburator. Had he done so, he would probably have found a new argument against the use of the oxyhydric light with carburetted gas.

We must conclude this article with an extract from the report of M. Louvet. His conclusions, although they strongly recommend the rejection of the request to lay down a system of mains in Paris, contains so high an opinion of M. Tessié du Motay's labors, that we cannot pass them in silence. "Your Commission," says M. Louvet, "believes that it should testify to the perseverance, to the investigations, and to the efforts of M. Tessié du Motay, thanks to which he has really found the means to produce oxygen under conditions more advantageous than has ever before been accomplished; he has made a discovery, which, sooner or later, will render immense service to industry. But for the present, the claims advanced to support the demand addressed you do not appear to be clearly enough established for the municipal authorities of the city of Paris to convert the canalization for the benefit of a system of lighting inapplicable for use in the public streets, and to assume thus, by a premature sanction, a great moral responsibility."

ELECTRICAL BATTERIES.*

From "The Engineer."

Upon two previous occasions the author has brought before the notice of the Society two portions of the subject of electric telegraphy, viz., the line or conductor, and the instrument. The author, however, feels that were he to omit the third part, the battery, he would be leaving the subject not simply incomplete, but shorn of one of its most essential elements.

The author has always regarded it as an apt illustration to draw a parallel between the electric telegraph and the steam engine. Most people have some acquaintance with the principles of the steam engine—what it is, and how it is constructed; whereas comparatively few have a clear conception of what an electric telegraph is, and how it is constructed; and it, therefore, appears to the author that some at least of the difficulty of the subject may be removed by the comparison. Following up this idea, the conductor may be compared to the steam pipe; the one conveys the electricity from its source—the battery—to act upon the instrument; the other conveys the steam from its source—the boiler—to act upon the engine. Again the instrument will bear a strict comparison with the engine, for both are mere machines constructed in such a manner as to be best influenced by the power conveyed to them. There then remains, in either case, the source of power. Now, what a steam engine would be without the boiler, a mere combination of inert pieces of mechanism, the electric telegraph would be without the battery. For this reason it has been thought that the battery forms a subject worthy of a separate notice.

The progress of telegraphy may indeed be regarded as dependent in a large degree upon our knowledge of the battery; and we may consider the great number of forms and constituent portions of which batteries

* From a paper read before the Society of Engineers (London) by Mr. E. G. Bartholomew.

are comprised affords a conclusive proof that the importance of the subject has not been overlooked. Few scientific subjects permit us to trace their rise and progress with that degree of minuteness and accuracy that electricity does, and particularly that branch of the subject which is at present before the Society—galvanic or voltaic electricity. Comparatively of recent birth as a science, we are left in no doubt as to the fact that but little more than 100 years since, the very existence of such an agent was unknown, nor was any very considerable progress made in discovery until a much later period. It is true that Sir H. Davy added to our stock of knowledge upon the subject, but his were rather investigations into the effects of the pile than attempts to modify its character; and we are not wrong in asserting as a broad fact that the improvements in batteries which have characterized late years are due in a great measure to the inefficient forms of batteries which existed, and to the necessity which electric telegraphy created for a moderately powerful battery, but, above all, one of a very constant kind. It is not, however, intended to enter into a history of the science of galvanic electricity, but to state briefly some of the leading features of the battery, its principles of construction, and the laws by which the force generated is governed.

The identity of electricity, from whatever source derived—whether from the friction of certain substances, from evaporation, from the chemical action set up under certain conditions, from magnetism, or from heat—is not doubted. It may differ in degree, but not in nature. If it be true, as has been asserted, that when we eat an egg with a metal spoon we generate electricity, the electricity so evolved will be identical with the flash which rends the oak. But certain substances, and certain combinations of substances, afford greater facilities for the development of the force than others, and it has been a part of the study of the modern philosopher to ascertain by what means the greatest amount of electrical force can be obtained at the least possible cost. Our subject has nothing to do with frictional or static electricity; it is a subject with which telegraphists are not concerned. The well-known story of Galvani's accidental discovery of a force hitherto unsuspected requires no repetition here; nevertheless we are bound to ascribe to him the honor of finding that certain metals when converted by a fluid would develop electricity; and when Volta subsequently produced a real battery by examining the laws of production and multiplying the combinations, he only followed in the path his predecessor had indicated.

The simplest voltaic combination is that in which two metals, as copper and zinc, having different affinities for oxygen, are immersed in a liquid capable of oxidizing one of them. Under such conditions a current of electricity is generated upon the surface of the most oxidizable, and passing through the liquid is given off at the other metal; and if a wire connect the two plates the current will continue to flow through it from the receiving to the generating plate so long as the necessary conditions are fulfilled. The fact that electricity is supposed to be evolved in the generating plate, but, instead of being developed there, passes through the liquid to the receiving or collecting plate, and is there given off, has procured for the latter the name of the + pole, whereas the — electricity remaining accumulated upon the surface of the generating plate has caused it to be termed the — pole. It must not, however, be lost sight of that the actual starting-point of the + is at the zinc or — pole. The expressions + and – will, therefore, require no further explanation.

As every metal has its own peculiar affinity for oxygen, so the various combinations of metals capable under the conditions just stated of developing electricity are numerous. It has, however, been ascertained that those metals or substances which differ most in their affinity for oxygen will form the most powerful combination. The order of the substances is as follows:—Graphite (carbon from gas retorts), platinum, silver, copper, iron, lead, tin, zinc. Hence a combination of graphite and zinc forms a powerful battery, and as both substances are comparatively cheap, this form of battery is of frequent occurrence. The great desiderata in a battery required for telegraphic purposes are its ability to overcome R (or resistance) and its constancy in action. The power a battery possesses of overcoming R is called its electromotive force. It has been stated that the difference of affinity for oxygen becomes a test of the value of substances as forming the elements of a battery, and this is correct so long as the liquid in which they are immersed remains the same. But some liquids act differently upon different

substances, and, therefore, the order in which they may be most advantageously combined will differ according to the liquid employed:—*i. e.*, by a reference to the list it is seen that copper stands higher upon the list than iron, and provided the liquid employed is dilute acetic sulphur or a solution of chloride of sodium, that is its correct position; but if a solution of salt of ammonia be used the order must be reversed.

There are two distinct characteristics in a battery dependent upon the order in which the same combinations are arranged:—*e. g.*, if one pair of large plates, say 12 in. by 12 in., be employed, the quantity of electricity generated will be considerable, although the electro-motive force will be small. If, however, a similar pair of plates be cut up into 144 pieces 1in. by 1in., and the 144 combinations be so arranged in 144 separate cells as that the — plate of the one be connected with the + plate of the next, and so on throughout the series, a battery is then obtained possessing 144 times less quantity, but 144 times more electro-motive force. Its latter property is termed its tension, and is applied to the entire series, the electro-motive force being more strictly applied to the specific energy of each combination. Knowing this fact, it becomes easy to utilize to the utmost the materials at disposal for the particular object needed.

In speaking of the tension of a battery it is usual to refer to the difference of tension between the extremes or poles, and to call one +, the other —, and these characteristics do really exist at the poles, although no conductor may unite them. Indeed, if a conductor connects them, the polarity is destroyed for the time, although constantly reproduced by the chemical action; there is a continuous flow of electricity from one pole to the other, and in this lies the great difference between galvanic or dynamic, and static electricity. It has been stated that the tension of a battery is increased by the number of combinations connected together in series; its quantity, however, remains the same as that of one only of the combinations in the series. This may be explained as follows: Assume the tension of a single pair of plates to be T when connected in series, that is + of one lot to — of another, the tension of each being T, the tension of the first pair passes on to the next, and adding its own tension to that of the second, the result is 2 T, and for any number n T; the size of the plates remaining. however, the same, there is no increase of quantity. But if all the + plates are connected together, and all the — plates, no increase of tension results, but we have n Q — Q, being the quantity in each pair. The effects of Q and T are different in some respects. If it is desired to obtain heat we retain large plates, because Q being large, the conductor cannot convey the whole, and the endeavor of the electricity to force its way through produces heat. The inability of a conductor to convey all the electricity may result from three causes: a low specific conductivity in the material composing the conductor, a small sectional area, or a very large conductor. If, however, it is desired to overcome resistance, it becomes necessary to diminish Q and increase T. Thus the electrician has at his disposal the means of suiting his battery to the requirements of the case.

A desirable object in all voltaic combinations is to utilize all the electricity developed. If a plate of pure zinc and a plate of iron be immersed in dilute ac. sulph., no chemical action will ensue unless the plates are connected, but if they touch, either directly or through the medium of a conductor, action immediately ensues on the surface of the zinc, a copious discharge of hydrogen bubbles escapes from it, and gradually the metal is dissolved, sulphate of zinc being formed. Stress has been laid upon the necessity of the zinc being pure, but pure zinc is difficult to obtain; the zinc of commerce is always more or less mixed with foreign substances, and, if impure, an action is set up locally upon its surface irrespective of its connection with the other plate, because a number of small galvanic circuits are formed upon it, and the result is the rapid consumption of the zinc, without any beneficial result. This local action must be carefully guarded against, and in order to do so it is usual to amalgamate the zinc with mercury; by this means the foreign and detrimental particles are covered, and the surface rendered homogeneous.

The action within the cell of a battery may be briefly explained thus: When the current flows through the liquid from the negative to the positive plate the water with which the acid is diluted becomes decomposed, the oxygen upon being set free uniting with the negative plate, forming an oxide which the acid converts into a sul-

phate, the hydrogen being set free in bubbles, not, however, until it has reduced some of the sulphate of zinc into a metallic state, which, unless prevented, forms upon the surface of the copper, and thus gradually converts the battery into one in which the two surfaces are similar, and therefore inoperative. There is yet another action set up in a battery under certain conditions, and it is due to the hydrogen which is set free. This gas passes over to the copper, and has a tendency to adhere to it; it is then found to alter its electrical state, and it becomes polarized. These two sources of deterioration, the deposit of zinc upon and the polarization of the copper, must be prevented in order to render the action of a battery constant. The method by which these objects is best effected is due to Daniell, and hence a battery in which the arrangement is carried out is called a "Daniell." It consists of a porous diaphragm interposed between the two metals, and having a strong solution of a salt of the metal itself upon that side of the diaphragm in which the copper plate is placed, together with some of the undissolved salts in crystals. By this means a constant electrolytic action is maintained, which resolves the salt (sulphate) into its constituents, the metal becoming deposited upon the plate, which hence always retains a surface perfectly clean and bright.

A battery so constructed presents the following action, so long as a conductor unites the two metals: The zinc is attacked by the ac. sulph., the water of the solution being decomposed; first oxide and then sulphate of zinc is formed, the hydrogen passes to the copper, decomposes the sulphate of copper, and deposits it in a metallic form on the surface of the metal. At the same time the acid constituent of the copper and sulphate passes to the zinc and continues the action upon that metal. The whole of this action ceases directly the connection between the plates is broken. From what has been stated it is evident that the development of electricity under the conditions named is obtained at the expense of the zinc and the sulphate of copper; and in order that this development shall be continuous a supply of the sulphate of copper in crystals must be maintained, for if this ceases the sulphate of zinc, which in small quanties is always sure to pass over into the copper side of the diaphragm, will become deposited upon the copper, one of the sources of error which it has been stated must be avoided. Other precautions have to be observed in the maintenance of uniformity, and in the development of the greatest amount of electricity, but those stated are of the greatest moment.

Passing from the Daniell to other combinations for the development of electricity, the Smee battery deserves special notice. In this battery a plate of amalgamated zinc is immersed in the same cell with a thin sheet of silver, upon the surface of which a coating of platinum is deposited by electrotypy. No diaphragm is required in this battery, and the liquid employed is sulphuric acid, diluted with water in the proportion of about 12 to 1 of acid. The platinum is deposited in a finely divided state, and presents a number of points which facilitate the passing off of the hydrogen. This battery is very energetic when the plates are connected after a period of rest, but for continuous action it is feeble. Where great energy is required the Grove battery becomes the most valuable of all combinations. In this arrangement amalgamated zinc and sheet platinum are employed, separated by a porous diaphragm. The zinc stands in a strong solution of acid sulphur, and the platinum in pure nitric acid. The action is as follows: The hydrogen element of the decomposed water, instead of passing over to the collecting plate and forming upon its surface, is entirely suppressed by the nitric acid, which becomes slowly deoxidized and converted into nitrous acid, which passes off in dense red fumes. This is a serious drawback to the use of this battery.

The "Marie-Davy" battery, which for a long period was extensively employed on the Continent, consists of zinc and carbon, and the liquid employed is a solution of the white crystalline bisulphate of mercury. Its tension is high, being at twelve to eight of Daniell's. One of the most valuable batteries for telegraphic purposes, where a constant current is not required, is the Leclanché. It consists of a zinc rod placed in a solution of common chloride of ammonia—sal-ammoniac—in which stands a porous pot containing a piece of carbon surrounded by a mixture of gas carbon and a peculiar form of peroxide of manganese broken into small pieces, but separated from any powder. When the battery is in action chloride of zinc is formed, which is soluble in sal-ammoniac, the peroxide of manganese is re-

duced to an oxide, and ammonia is formed. When the sal-ammoniac has become nearly removed from the liquid it cannot dissolve the chloride of zinc, and the liquid becomes milky; more of the salt must then be added.

In a battery consisting of many plates in a series all the plates should be of the same size, and all the cells in the same condition, as one faulty cell will not only rob the entire series of the value of itself, but will injure the action of the whole. Every cell of a battery should therefore be periodically tested separately, and if the quantity of any one cell be less than the average of the others it should be rejected or remedied. The battery itself, although the source of power, yet possesses resistance to the passing of its own current. The resistance of a battery may be measured by the following method: Connect a tangent galvanometer in circuit with the battery to be measured, and by means of a shunt reduce its deflection to, say, 30 deg., which note. Then add more resistance to the circuit until the deflection is reduced to one half—in other words, double the resistance of the entire circuit. Then measure the R of the circuit without the battery, and deduct it from the R last added; the remainder will be the R of the battery: *e. g.* let the R of the galvanometer in the first instance be 40, then if an extra R or so be required to value the deflection, the R of the battery will be 40.

Any allusion to other sources of electrical force available for telegraphic purposes, as for instance magnets, has been avoided, reference having been made to them in a previous paper read by the author before the Society. It is only necessary to add, that as the battery is one of the great elements of expense in the maintenance of a telegraph, any form which reduces the cost without detriment to its efficiency is desirable. Batteries are required for various purposes. In block signalling a constant current is required, and the battery wastes more rapidly, the cost of maintenance being in a well constructed battery proportionate to the work done; whereas others require only to be used at intervals, and to display great energy for a brief period.

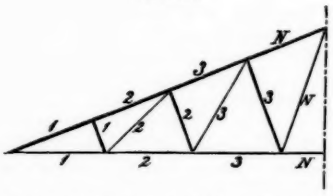
DESIGNS AND PROPORTIONS OF POINTED ROOFS.*

By THOS. GILLOTT.

After the comprehensive treatment that the strains on roof trusses have received at the hands of numerous authorities, some apology may be thought necessary for bringing this subject forward. But, so far as the author is aware, no conditions of absolute economy in roof construction have been laid down, except those contained in a communication which he had the honor to present to the British Association, at their last Edinburgh meeting; an abstract of which appeared in the "Engineer," of August 11, 1871. The substance of that communication is included in the present one; and for a demonstration of some results stated in the text, reference must be given to the mathematical investigation which forms an appendix to this paper.

Professor Rankine ("Civil Engineering," p. 468), after treating the mechanics of the subject, gives the angles of slopes for roofs covered with metallic sheets 4 deg., slates, tiles, and boards from 22½ deg. to 30 deg., as being the flattest generally used; but apparently without reference to any fixed law (except the mention of Mr. Hay's theory of beauty); and the great differences in the designs and proportions of numerous existing pointed roofs, in which æsthetical effect has not been aimed at, must have been observed by many, other than those in

FIG. 1.



whose province it is to design these structures; and it may be fairly submitted that where beauty is not an especial object, the greatest economy practicable ought to be secured. In the investigation of the latter condition, the governing theoretical principles will be first deduced, and then the ap-

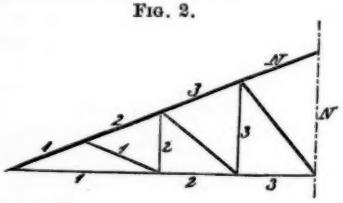
* From a paper read before the Leeds Association of Foremen Engineers.

plication to, and modifying extent of practice considered.

The diagrams 1 to 7 (on drawing) include most if not all forms of trusses usually met with.

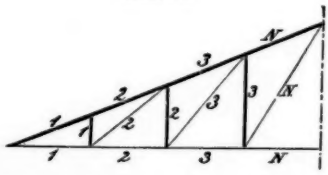
The first three may be called types of their respective forms, from the fact that the

FIG. 2.



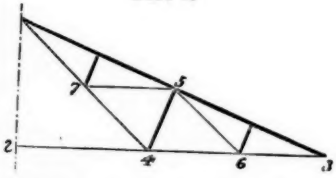
number of bays formed by secondary trussing (4 on those drawn), may be increased or diminished; observing the principles, in Fig. 1 to place the struts at right angles to the principal rafter, and the tie braces diagonally; in Fig. 2, the suspending rods vertically, and struts diagonally; and in Fig. 3,

FIG. 3.



the struts vertically, and ties diagonally; and supporting the rafters at as many points as may be found necessary. Figs. 4 to 7 are particular forms; 4 and 5 having four, and Figs. 6 and 7 three divisions formed by secondary trussing. Two things have to be determined: first, the most economical kind

FIG. 4.



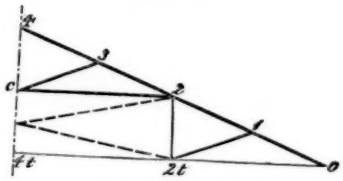
of truss, and secondly the inclination that ought to be given to the rafters, in order to render the cost a minimum.

The sectional area of any member of a truss should, obviously, be proportional to the strain which it is required to transmit; and the comparative weight of any two members will vary as the strains upon each of them multiplied by their respective lengths. The summation of these products for any description of truss will, consequently, be a co-efficient representing the weight, bulk, or cost of it; and if these products are compared for each form, that which has the smallest will be the most economical one.

The strains on the members have been investigated, and are expressed in the formulæ given in the appendix; and the nature of the stresses are represented on the diagrams by thin lines for tension, and thick ones for compression.

In theoretical economy, the types shown by Figs. 1 and 2 are equal; and the values of the co-efficients in the following table are

FIG. 5.



for trusses, with four equal divisions in the rafters, and a rise of $\frac{1}{8}$ the span (W = total distributed load, and c = half span):

TABLE 1.

No. of Fig.	Bars in Tension.	Bars in Compression.
1 and 2.....	2 203125 W c	2 403125 W c
3	2.315625 W c	2 515625 W c
4	2 3375 W c	2.5375 W c
5	2.10625 W c	2 281875 W c

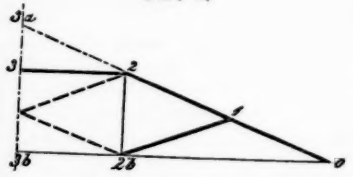
Figs. 6 and 7, compared with trusses of types 1 and 2 with three divisors in the rafter, and as—

$$\left\{\begin{matrix}1.9888\ W c\\ 2.1666\ W c\end{matrix}\right\} : \left\{\begin{matrix}2\ 2166\ W c\\ 2.4166\ W c\end{matrix}\right\} : \left\{\begin{matrix}2.1222\ W c\\ 2.3222\ W c\end{matrix}\right\}$$

It may be remarked that 5 and 6 would only be in stable equilibrium under an equally distributed passive load; and if diagonals were inserted as shown by dotted lines, in Fig. 5, equal to the area of the collar beam $2-c$, and in Fig. 6 equal to the small strut $1-2b$, the products for bars in compression would be increased to 3.238125 and 2.4888 Wc respectively. The weight, bulk, or cost may be obtained

from these products for principals of any given span, to carry a given load, by multiplying each product by the weight, bulk, or cost of material required to transmit a unit of strain (say 1 ton) through a unit of length (say 1 ft.); let the material be

FIG. 6.



wrought iron, and the strains per sq. in. 4 tons for ties and $1\frac{1}{4}$ tons for struts; then, the weights of principals 60 ft. span, 12 ft. rise, sustaining an equally distributed load of 8 tons, would be

Types 1 and 2, four divisions
$= \left(2.203125\frac{3\frac{1}{3}}{4} + 2.403125\frac{3\frac{1}{3}}{1\frac{1}{4}}\right)8\times30 = 1978.6$ lbs.

Type 3, four divisions
$= \left(2.315625\frac{3\frac{1}{3}}{4} + 2.515625\frac{3\frac{1}{3}}{1\frac{1}{4}}\right)8\times30 = 2073.1$ lbs.

Fig. 4, four divisions
$= \left(2.2375\frac{3\frac{1}{3}}{4} + 2.5375\frac{3\frac{1}{3}}{1\frac{1}{4}}\right)8\times30 = 2091.5$ lbs.

Fig. 5, four divisions
$= \left(2.10625\frac{3\frac{1}{3}}{4} + 2.28175\frac{3\frac{1}{3}}{1\frac{1}{4}}\right)8\times30 = 1881.6$ lbs.

Fig. 6, three divisions
$= \left(1.9888\frac{3\frac{1}{3}}{4} + 2.1666\frac{3\frac{1}{3}}{1\frac{1}{4}}\right)8\times30 = 1784.4$ lbs.

Fig. 7, three divisions
$= \left(2.2166\frac{3\frac{1}{3}}{4} + 2.4166\frac{3\frac{1}{3}}{1\frac{1}{4}}\right)8\times30 = 1990$ lbs.

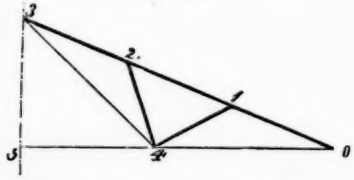
The weights for 5 and 6 are without stiffening diagonals; if they are included, the weights would be respectively increased to 2,493.66 and 1,990.67 lbs. It must be observed that these weights are the theoretical minima, and must always be exceeded in practice by the weights of joint covers, material rendered useless by punching when plain flat ties are used, and excess of material in the divisions of the rafter nearest the apex when its section is uniform throughout.

It will be obvious that the greater the rise—or angle of inclination of the rafter—the greater will be the weight, area, and, consequently, cost of the covering; but an inspection of the formulæ expressing the products of the length of bars multiplied by the strain on them, in terms of the weight, span, and rise, will show that the co-efficients are, approximately, directly as the square of the span, and inversely as the rise; therefore, within practical limits, a truss can be made to carry a given load with less material in proportion to the increase given to the rise. Again, the cost of the material in the principal and covering will influence the pitch; for with trusses of the same material, the more expensive covering (such as glass, zinc, etc.) requires a lower pitch than the cheaper descriptions (slates, tiles, etc.). The method of determining the cost of the principal has been before explained; and if the value of the covering carried be added to it, the total cost of one bay of roofing will be arrived at. By differentiating the expression for this total cost ($=y$) with respect to the angle of inclination ($=\theta$) of the rafter in order to obtain its minimum value, the following differential equation to the angle of least cost is obtained:

$$\frac{dy}{d\theta} = 4c(aq+bq_1)\tan.^4\theta + 3e\tan.^3\theta + 2c(aq+bq_1)\tan.^2\theta - c(a+b)p = 0$$

in which c = half span, e = cost per square unit of covering, a and b = the respective costs of ties and struts to transmit a unit of strain through a unit of length, p, q, and q_1 are factors depending for their values on the weight per square unit, and the number of divisions in the rafter formed by secondary trussing. It will be observed that the unknown tangent increases with the span; or, for a larger span of roof a greater angle of inclination should be given to the rafters than for a smaller one.

FIG. 7.



The theory of economical roof construction being stated, it is necessary to consider to what extent practice will modify it; and it is mainly in the choice of the best form of principal where departures are advisable. Without stiffening diagonals, Nos. 5 and 6 claim the highest places in the order of

economy; but their ability to resist changes of form under slight inequalities of loading, depending on the rigidity of the joints, in iron trusses the diagonals could not be well omitted; but with timber as the material the joints can be made more stiff and the forms better suited for it. This is fully borne out by the extent to which they have been adopted. On account of the ridge not being supported by No. 6, an additional strain is thrown upon the spars, and when this form is used the spars would require to be made stronger than with the others. Of the remaining forms, only one, viz., No. 2, can well be employed in timber; and with two divisions in the rafter it becomes the well-known king-post truss. Excluding Nos. 5 and 6, for the reason before given, the choice lies between Nos. 1 and 2 for iron principals, and the simplicity of these forms is not, in the author's opinion, less than the remaining ones. If the external dimensions of sections suitable for struts could always be maintained in that ratio to the length required by the laws which govern the resistance of pillars, so that the crushing force per square unit was the same for both kinds, Nos. 1 and 2 would be, theoretically and practically, of the same degree of economy. But it is not possible to procure sections of such small thickness to obtain this; therefore the long struts of No. 2 are more costly than the short ones of No. 1; and the latter is, consequently, selected as the most favorable type to adopt. But in the case of three divisions in the rafters, No. 7 is a very good form, and one extensively used.

The cost of material for principals and covering is so variable, that the exact inclination of the rafters which will secure the maximum degree of economy must be determined for each individual case; but as a guide and an illustration, the following tables of pitches have been calculated upon the assumptions stated.

Let the principal be of wrought iron, the ties made of flat bars, and in their manufactured state be worth 12s. per cwt.; which, with allowances of 50 per cent. for punching and 70 per cent. for joints, on the net material strained to 4 tons per sq. in., makes the value of $a = 2.358$d., and the struts at 12s. 6d. per cwt. sustaining a gross average strain of $1\frac{1}{2}$ tons per sq. in., making $b = 3$d. Let the covering be slates, on timber laths, spars, and purlins, worth 6d. per sq. ft.$= e$; and the weight 15 cwt. per 100 sq. ft.; then for types 1 and 2 the most economical pitches are given in the following table:

TABLE 2.

Span.	Divisions in Rafters.	θ	Tang. θ.	Rise.
Feet.		° ′		Feet.
20	2	19 31	.3545	3.545
25	2	20 48	.38	4.75
30	2	21 50	.4006	6.009
35	3	22 30	.415	7.2625
40	3	23 17	.4304	8.608
45	3	23 56	.4436	9.948
50	4	24 5	.447	11.175
55	4	24 31	.456	12.54
60	4	24 57	.4651	13.953

Ridge, eaves, and principal shoes, being constant, are not considered in the costs that determine the angle.

Again, let the principals be as last, but the covering of the value of 9d. per sq. ft., or that of corrugated galvanized iron on angle iron purlins; then (assuming the weight equal) the following table gives the pitches to fulfil the conditions of maximum economy:

TABLE 3.

Span.	Divisions in Rafters.	θ	Tang. θ.	Rise.
Feet.		° ′		Feet.
20	2	17 23	.3131	3.131
25	2	18 32	.3352	4.19
30	2	19 33	.355	5 325
35	3	20 20	.3707	6.487
40	3	21 7	.3862	7.724
45	3	21 37	.3964	8 919
50	4	21 59	.4036	10 09
55	4	22 27	.4132	11.363
60	4	22 53	.4222	12.666

Up to 30 ft. span, corrugated iron roofs of the form of a circular segment may be constructed without principals; this investigation, however, does not extend to circular or other roofs than plain pointed ones. As a third example, let the principal be of wood, sustaining gross strains in tension and compression of 200 lbs. and 250 lbs. per sq. in. respectively, and the cost, including fastenings, 3s. per cubic foot, making the values of a and b, 2.8d. and 2.25d. Let the covering be worth 6d., and weigh .0075 tons per sq. ft. (as in the first example), then the pitches calculated from the formula, are:

TABLE 4.

Span.	Description of Truss.	θ	Tang θ	Rise.
Feet.		° ′		feet.
20	No. 1, 2 divisions.	19 18	.35	3.5
25	" " "	20 32	.3744	4.68
30	" " "	21 35	.3956	5.934
35	No. 6, 3 divisions.	23 5	.4263	7.46
40	" " "	23 56	.4439	8 878
45	" " "	25 5	.468	10 53
50	No. 5, 4 divisions.	25 30	.4709	11 922
55	" " "	26 7	.49	13.475
60	" " "	26 40	.502	15.06

The pitch for small roofs would require to be slightly increased, if it were taken into consideration that small roof trusses are somewhat more expensive, per unit of material, than large ones; but this would be nearly counterbalanced by the necessity of slightly increasing the lap of the slates (and consequently cost of the covering), in order to render a flat roof water-tight. To prove that the cost is a minimum, let a roof be 60 ft. in span, and the costs as in Table 2 (where the rise is given nearly 14 ft.); then, if the rise had been 2 ft. more or less, the cost would have amounted to:

Cost.	14 feet rise.	16 feet rise.	12 feet rise.
Ties	1034 146	973.1	1133.02
Struts	1471.74	1421.64	1572.36
Covering	5958	6120.	5815.8
Total	8463.886	8514.74	8521.18

For a roof of the same span, when the costs of material are as in Table 4 (where the rise is given 15 ft.), when made 14 ft. and 16 ft. instead, the costs of equal lengths are represented by

Cost.	15 feet rise.	14 feet rise.	16 feet rise.
Ties	1089.52	1142 8816	1043.22
Struts	987	1020.825	958 78
Covering	6037.2	5958.	6120.
Total.....	8113.72	8121.70666	8122.

On account of the great amount of waste at the joints in using timber to transmit tensile stresses, iron is the cheaper material for ties; but for struts, timber is less costly than iron. Combinations of the two, however, are not altogether desirable, and are opposed to the best modern practice. If no difficulty is found, or great expense incurred, in rolling sections of Bessemer steel of small thickness (compared with iron) and suitable external dimensions for compression bars, it is very probable that this or some other steel, may supersede wrought iron in respect of cost alone to the extent of 25 per cent.

The author very much doubts the economy of using cast in combination with wrought iron for roof trusses, owing to the great amount of additional material usually (and necessarily) provided to guard against accidental breakage; this, and the fact of their unequal elasticities, should, in his opinion, cause this combination to be abandoned; and, for a similar reason, the use of cast sockets at the joints of wrought-iron bars.

The construction of timber trusses is so well understood that little need be said about it; but one point calls for notice, viz., the use of a simple bolt in queen posts screwed through the main tie into a nut recessed in the post. The strut which abuts at the intersection of the queen and main tie communicates a horizontal strain to the latter as well as a vertical one to the former; which requires that either queen or strut should be morticed into the tie, which is seldom done.

In the choice of material, that of the covering is generally fixed, and its cost known; but as a guide in selecting that for the principal, the cost of transmitting an unit of strain through an unit of length will, generally, indicate what should be adopted.

In conclusion, the author anticipates it may be urged that an unnecessary degree of refinement has been introduced in connection with this subject; still, similar investigations with respect to bridges afford a precedent for this, and, it is hoped, will be its apology.

THE HOOSAC TUNNEL.—Between the west end of the tunnel and the central shaft there is a little more than half a mile of the mountain to be bored through. The total length of the tunnel will be a little more than 4¾ miles.

ON THE PREVENTION OF AND MEANS OF ARRESTING PUTREFACTION.

From the "Journal of the Society of Arts."

The following is an abstract of a series of papers read before the Royal Society, by Dr. F. Grace Calvert, F. R. S., and which give the results of a very important series of experiments :—

ON PUTREFACTION.

This paper is intimately connected with those I have already published on protoplasmic life and the influence it exerts on putrefaction.

I have already shown that when albumen from a new-laid egg is introduced into pure distilled water, and communication with the atmosphere prevented, protoplasmic life does not appear. If the same solution, however, be exposed to the atmosphere for from 15 to 45 min., minute globular bodies appear, having an independent motion, which I denominate monads. The time required varies according to the time of the year, the amount of moisture present in the atmosphere, and the temperature.

Although M. Pasteur has already noticed the meteorological conditions which influence that life, he has not noticed the extraordinary rapidity with which the fluids are impregnated, and that this impregnation is proportional to the surface exposed.

On the 18th of May, 1871, two portions of albumen, measuring 400 grains, were placed, the one in a test-tube having a diameter of $\frac{3}{4}$ in., the other in a test-glass which at the surface of the liquid had a diameter of 2 in. In the tube vibrios appeared after 12 days, whilst in the glass only 5 days were required for their development. If in place of pure distilled water the water supplied by the Manchester Corporation (which is one of the purest waters in England) was used, the time required for the development of vibrios in a test-tube was only 24 hours.

These experiments prove that the rate of development of vibrio-life is influenced by the extent of surface exposed.

M. Pasteur has already demonstrated that oxygen is essential to the life of the Mucedines, but I am not aware that it has been proved that this gas is necessary to the existence of vibrio-life.

In the hope of throwing some light on this subject, the following experiments were made :—

Into each of five glass bulbs equal volumes of a solution of albumen in Manchester water were placed, and the first left in contact with the atmosphere for 24 hours, after which the ends of the tube were hermetically sealed about 2 in. on each side of the bulb. After passing oxygen, hydrogen, nitrogen, and carbonic acid over the other four solutions, the tubes were also hermetically sealed. These tubes were kept closed for 27 days, during which it was observed that the albumen in the bulb containing oxygen speedily became turbid, then the one containing air, while the other three remained clear. After this period the tubes were broken, and the contents examined. A large quantity of vibrio-life was found in those containing oxygen and common air, whilst those containing nitrogen, carbonic acid, and hydrogen contained very small quantities, that with hydrogen the least —thus proving that oxygen is an essential element to the production of putrefactive vibrios.

In further support of this view, I may state that, under certain conditions, these animalcules produce such an amount of carbonic acid and other gases, as to exclude oxygen to such an extent that their own development and life are impaired.

This is easily proved by taking albumen full of animalcules, but not emitting any putrid odor, and placing it in test-tubes, closing some and leaving others open. If these tubes are examined after a few weeks, it will be observed that in those left in the air life has much increased, and they emit a very putrid odor; whilst the life in the closed tubes not only has not increased, but appears to be in a dormant condition; for if the corks are removed and the fluid again comes in contact with the oxygen of the air, its activity returns. The albumen also in the closed tubes does not emit any putrid odor.

M. Pasteur has also found that oxygen was necessary to the vibrios of putrefaction, although the same gas destroyed those produced in butyric fermentation; but he has not made any experiments to show that the products emitted by such vibrios are preju-

dicial to their development, and even to their power of locomotion.

Having stated above that liquids exposed to the atmosphere become impregnated with monads, I will try to describe their gradual development into vibrios, and their ultimate transformation into microzyma.

A few hours after the albuminous fluid becomes impregnated, the monads, which have a diameter of about $\frac{1}{12800}$ of an inch, appear to form masses. Then some of the monads become elongated into vibrios, which, though attached to the mass, have an independent motion; so that as the force exerted by the vibrios predominates towards one or another direction, so is the mass moved over the field of the microscope. As the development proceeds, the mass is broken up, and ultimately each vibrio has an independent existence, and may be seen swimming or rolling about in the fluid. Their size at this stage is about $\frac{1}{7000}$ of an inch. These, which I call ordinary vibrios, gradually grow into long vibrios, which attain a length of $\frac{1}{6400}$ of an inch.

These long vibrios gradually become changed into cells, which I have called microzyms. The first process in the transformation is its division into two independent bodies. One extremely faint line appears across the centre of the animalcule, and increases in distinctness until the vibrio appears like two smaller vibrios joined together. The separation takes place and each part acquires an independent existence. These parts again divide, and the process of subdivision is carried on until they appear to be nothing more than cells, which have a swimming power so great as to pass over the field of the microscope with rapidity.

After 12 or 18 months, all the vibrios disappear and are replaced by microzyms, either in motion or at rest. If these microzyms are placed in a solution of fresh albumen, vibrios are abundantly developed. The apparent explanation of this fact is, that in the fresh albumen they have all the circumstances favorable to their growth and reproduction, while the putrid albumen has become so completely modified as to be incapable of affording them the requisite conditions for reproduction.

I may also notice that at the same time a deposit has taken place, which, under the microscope, appears to consist of shoals of small particles of matter which have no life. The solution has now become perfectly clear, possesses considerable refractive power, and has lost the property of becoming coagulated by heat.

The albumen solution does not emit a putrid odor until after the formation of the above-mentioned deposit, and the amount of odor is in direct ratio to the number of vibrios present.

I remarked during the investigation, the presence of several other forms of animalcules which contribute to the decomposition and putrefaction of proteine substances, the description of which will be found in the original memoir.

ON THE RELATIVE POWER OF VARIOUS SUBSTANCES IN PREVENTING PUTREFACTION AND THE DEVELOPMENT OF PROTOPLASMIC AND FUNGUS LIFE.

To carry out this series of experiments, small test-tubes were thoroughly cleansed, and heated to dull redness. Into each was placed 26 grammes of a solution of albumen, containing one part of white of egg to four parts of pure distilled water, prepared as described in my paper on protoplasmic life. To this was added $\frac{1}{1000}$ or .026 gramme of each of the substances the action of which I desire to study.

The reason why I employed one part in a thousand are twofold. First, the employment of larger proportions would, in some instances, have coagulated the albumen. Secondly, it would have increased the difficulty of observing the relative powers of the most efficacious antiseptics in preventing the development of the germs of putrefaction or decay.

A drop was taken from each of the tubes and examined under a miscroscope having a magnifying power of 800 diameters. This operation was repeated daily with the contents of each tube for thirty-nine days, and from time to time for eighty days. During this time the tubes were kept in a room the temperature of which did not vary more than 3 deg., namely, from 12.5 deg. C. to 15.5 deg. C.

In order the better to show the influence of the antiseptics used, I examined two specimens of the same solution at the same time, one of which was kept in the laboratory, the other in the open air.

A marked difference was observed in the result; the one kept outside becoming impregnated with animal life in less than half the time required by the other, while as many vibrios were developed in six days

in the tube kept outside as were developed in thirty days in the tube in the laboratory.

A summary of the results of the experiments is given in the following table, in which the substances are grouped according to their chemical nature :—

	Days required for development of Fungi.	Vibrios.
1. Standard Solutions.		
Albumen kept in laboratory for comparison	18	12
Albumen exposed outside laboratory	none	5
2. Acids.		
Sulphurous acid	21	11
Sulphuric acid	9	9
Nitric Acid	10	10
Arsenious acid	18	22
Acetic Acid	9	30
Prussic acid	none	9
3. Alkalies.		
Caustic soda	18	24
Caustic potash	16	26
Caustic ammonia	20	24
Caustic lime	none	13
4. Chlorine Compounds		
Solution of chlorine	22	7
Chloride of sodium	19	14
Chloride of calcium	18	7
Chloride of aluminium	21	10
Chloride of zinc	53	none
Bichloride of mercury	81	none
Chloride of lime	16	9
Chlorate of potash	19	17
5. Sulphur Compounds.		
Sulphate of lime	19	9
Protosulphate of iron	15	7
Bisulphite of lime	18	11
Hyposulphite of soda	18	11
6. Phosphates.		
Phosphate of soda	17	13
Phosphate of lime	22	7
7.		
Permanganate of potash	22	9
8. Tar Series.		
Carbolic acid	none	none
Cresylic acid	none	none
9. Sulphocarbolates.		
Sulphocarbolate of potash	17	18
Sulphocarbolate of soda	19	18
Sulphocarbolate of zinc	17	none
10.		
Sulphate of quinine	none	25
Picric acid	19	17
Pepper	none	8
Turpentine	42	14
11.		
Charcoal	21	9

In comparing the results stated in the above table, the substances can be classed under four distinct heads, viz., those which prevent the development of protoplasmic and fungus life; those which prevent the production of vibrio-life, but do not prevent the appearance of fungus-life; those which permit the production of vibrio-life, but prevent the appearance of fungus life; and those which do not prevent the appearance of either protoplasmic or fungus life.

The first class contains only two substances, carbolic and cresylic acids.

In the second class also there are only two compounds, chloride of zinc and bichloride of mercury.

In the third class there are five substances, lime, sulphate of quinine, pepper, turpentine, and prussic acid.

In the fourth class are included the remaining twenty-five substances.

The acids, while not preventing the production of vibrio-life, have a marked tendency to promote the growth of fungus-life. This is especially noticeable in the case of sulphuric and acetic acids.

Alkalies, on the contrary, are not favorable to the production of fungus-life, but promote the development of vibrios.

The chlorides of zinc and mercury, while completely preventing the development of animalcules, do not entirely prevent fungus-life; but I would call special attention to the interesting and unexpected results obtained in the cases of chlorine and bleaching-powder. When used in the proportion above stated they do not prevent the production of vibrio-life. In order to do so they must be employed in excess; and I have ascertained, by a distinct series of experiments, that large quantities of bleaching-powder are necessary. I found that part of the carbon was converted into carbonic acid, and part of the nitrogen was liberated.

If, however, the bleaching-powder be not in excess, the animal matter will still readily enter into putrefaction. The assumption on which its employment as a disinfectant has been based, namely, that the affinity of the chlorine of hydrogen is so great as to destroy the germs, is erroneous.

The next class to which I would call your attention is the tar series, where neither the carbolic nor the cresylic acid fluids gave any signs of vibrionic or fungus life during the whole eighty days during which the experiments were conducted.

The results obtained with sulphate of quinine, pepper, and turpentine, deserve notice. None of them prevent the development of vibrio-life; but sulphate of quinine and pepper entirely prevent the appearance of fungi. This fact, together with the re-

markable efficacy of sulphate of quinine in intermittent fever, would lead to the supposition that this form of disease is due to the introduction into the system of fungus germs; and this is rendered the more probable if we bear in mind that these fevers are prevalent only in low, marshy situations, where vegetable decay abounds, and never appear to any extent in dry climates, even in the midst of dense populations, where ventilation is bad and putrefaction is rife.

The results obtained in the case of charcoal show that it possesses no antiseptic properties, but that it prevents the emanation of putrid gases, owing to its extraordinary porosity, which condenses the gases, thus bringing them into contact with the oxygen of the atmosphere, which is simultaneously condensed.

The above results have been confirmed by a second series.

A series of experiments was also undertaken, substituting gelatine for albumen, and was continued for 47 days.

Vibrios appeared in two days in the standard gelatine solution, and bacteria after four or five; and during the whole time of the experiment, life was far more abundant than in the albumen solution. A distinct putrid smell was emitted after 26 days.

With bleaching-powder it took 20 days for life to appear instead of seven, as in the case of albumen; while at no time during the 27 days which remained was life abundant. No putrid odor was emitted, but a mouldy one could be detected on the 13th day.

With chlorine solution vibrio life was observed only after 40 days; no putrid nor mouldy smell was given off at any time.

The protosulphate of iron gave, with this solution, results quite different from those with albumen, in which, it will be remembered, vibrios appeared in seven days, and fungi after fifteen; whilst with gelatine neither protoplasmic nor fungus life appeared during the time the experiments were continued.

Another substance, arsenious acid, also presented a marked difference in its action in the two solutions; for although with albumen 22 days elapsed before vibrios were present, and 18 before fungi, with gelatine animal life appeared after two days, and at no time did any fungi exist. The effects of the other substances with gelatine were so similar to those with albumen, that it is unnecessary to state them here.

ON THE RELATIVE POWER OF VARIOUS SUBSTANCES IN ARRESTING PURTREFACTION AND THE DEVELOPMENT OF PROTOPLASMIC AND FUNGUS LIFE.

This series of experiments was undertaken as being complementary to those described in my last paper, and consisted in adding to a solution of albumen, swarming with microscopic life, one-thousandth part of the substances already enumerated in that paper, and examining the results produced immediately after the addition of the substances, and after 1, 6, and 16 days; but in this abstract only the results obtained in the first and last cases will be noticed.

The solutions were placed in test-tubes similar to those described in my last paper.

The experiments were begun on the 30th September, 1871, the solutions being kept to a temperature of 15 deg.—18 deg. C.

In the standard solution the amount of life and putrescence increased during the whole of the time.

The first class includes those substances which completely destroyed the locomotive power of the vibrios immediately, and completely prevented their regaining it during the time experiments were conducted:

Cresylic acid.

The second class contains these compounds which nearly destroyed the locomotive power of all the vibrios present when added, and afterwards only one or two could be seen swimming about in each field:

Carbolic acid, sulphate of quinine, chloride of zinc, and sulphuric acid.

The third class are those which acted injuriously on the vibrios on their addition, leaving only a small number retaining the power of swimming, but which allowed the vibrios gradually to increase in number, the fluid, nevertheless, containing less life after 16 days than the standard putrid albumen-solution:

Picric acid and sulpho-carbolate of zinc.

The fourth class includes those substances which acted injuriously at first, but permitted the vibrios to regain their former locomotive power, so that the fluid after 16 days contained as much vibrio-life as the standard putrid albumen:

Chloride of aluminium, sulphurous acid, and prussic acid.

The fifth class contains those compounds which acted injuriously at first, destroying the locomotive power of most of the vibrios, but which afterwards permitted the vibrios

to increase more rapidly than in the standard albumen-solution:

Bleaching-powder, bichloride of mercury, chlorine-solution, caustic-soda, acetic and nitric acids, sulphate of iron, and the sulphocarbolates of potash and soda.

The sixth class contains those compounds which exercised no action on the animalcules, either at first or after 16 days:

Arsenious acid, common salt, chloride of calcium, chlorate of potash, sulphate of lime, bisulphite of lime, hyposulphite of soda, phosphate of lime, turpentine, and pepper.

The seventh class includes those substances which favor the production of animalcules and promote putrefaction:

Lime, charcoal, permanganate of potash, phosphate of soda, and ammonia.

INJECTORS.

By P. H. ROSENKRANZ.

Translated from "Zeits. des Vereines Deutscher Ingenieure." (Condensed.)

We propose to give a brief account of the development of the Gifford injector, as well as a description of the other best-known injectors.

The fundamental principle of the injector was applied in various ways before Gifford's invention. This principle consists in the action produced by a stream of fluid or gas issuing, under pressure, from a pipe into a closed chest or tube; that is, by the rarefaction and consequent suction of another fluid. This action was known in 1570 to Vitriv and Philebert De Lorme.

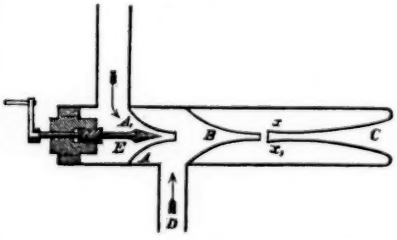
Next in mention is the well-known locomotive blast-pipe, applied by Stephenson in 1820. The action of these pipes was afterwards explained by Zeuner, and further results are due to Prüsman.

Gurney's steam ventilator acted by means of steam passing through one pipe and sucking air through another connected with it. This simple apparatus was afterwards employed by Nagel and Kaemp in centrifugal pumps to prevent filling. Besides these, may be mentioned Thompson's pump, the water bellows, and Danchell's steam manometer.

But the most extensive and familiar application is presented in the injector represented in form and operation in Fig. 1. Steam passes through A_1, and thence after the withdrawal of the spindle E, passes through the nozzle A, drawing water from D; this condenses the steam and mingles with it, then passes along B and enters the boiler through C.

It is not to be denied that the injector differs materially from the apparatus above mentioned. The common quality is that the drawing fluid is steam, while that drawn is water; but there occurs a new phenomenon which makes it possible to apply this process to the feeding of boilers; and in this mainly consists the novelty of Gifford's idea. This phenomenon is the change of density. In the apparatus heretofore mentioned the fluids merely mix behind the opening A, and are discharged together through B, but in the case of the injector a condensation takes place. Theory and practice show that

FIG. 1.



the consequence of this is, that the mixture is discharged through B and C with greater velocity than that with which the water alone would be discharged under a pressure equal to that of the steam in the boiler. By proper choice of nozzles this increase of velocity can be made greater, and the necessary over-pressure is obtained to do the work of the injector in overcoming the pressure in the boiler and the friction in the pipe, and in lifting the feed valve. In order to prevent too great a diminution of the work done, this over-pressure must be kept at a minimum limit.

In considering the action of the injector, regard must be had to 3 nozzles: the steam nozzle A (Fig. 1), the most important, as the injector cannot act without this; the mixing nozzle B, in which mixture and condensation take place; and the one most important with regard to the formation of the stream

of water, the over-pressure nozzle C; which, by means of the contraction at $\chi\psi_1$ makes possible the discharge into the water in the boiler, and also by its suction regulates in a certain degree the performance of the injector.

The bores of these three pipes may be very different if their ratios remain the same. Hence there result many variations in the construction of injectors.

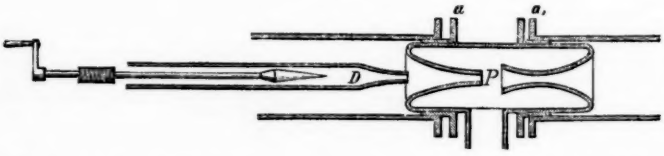
The best angle of convergence for the steam nozzle is one of 5 deg. Its connection with the mixing pipe is dependent on the tension of the steam, because sometimes more, at other times less water, is required for condensation. The mixing pipe is generally large at the entrance and slightly conical; it is so adjusted to the over-pressure pipe that the stream strikes the narrowest place in C.

The over-pressure pipe should approximate the form of a parabola. There must be a space between this and the mixing pipe to give passage to the water so as to regulate the ratio between steam and water.

With reference to the dimensions at the narrowest place in this pipe, the majority of injectors agree; but they differ very greatly in the dimensions of the steam pipe. Independently of details of construction, to be explained hereafter, that injector is the most advantageous which gives the greatest performance with the least dimensions of steam pipe and least consumption of steam.

We next consider the performance of the injector as compared with that of the steam pump. We arrive at the result that an injector, heat not considered, consumes 7 times as much steam as a steam pump of equal performance. But with regard to the heat which the steam communicates to the feed-water the result is by no means so unfavorable. Exact experiments have shown that with an injector, 1 kilog. of steam heats 14 kilog. of water, and introduces it into the boiler; increasing the temperature of the water about 30 deg. R. The heat expended in warming the water amounts to 81 @ 82 per cent.; that converted into work to 19 @ 18 per cent. There is no direct loss

FIG. 2.



of heat. The lower the steam tension and the slower the discharge of water, the more the heat imparted to the boiler. It is important that the nozzles should be as large and short as possible; that bends should be avoided as much as may be; and that proper valves should be employed so that work may not be lost in shocks. It must be admitted that in many cases where there is little steam and much water at high temperature, as in condensing engines, the pump is to be preferred to the injector. So these are cases in which the latter is to be preferred. In the later injectors, which draw warm water at 35 deg. R., the useful effect and availability is greatly increased.

We shall now describe the most important of the contrivances of this sort.

The construction of Gifford's apparatus is so well known that we dispense with description, confining ourselves to mention of its defects.

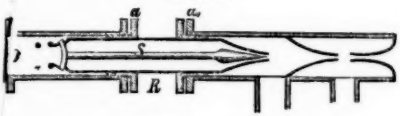
Two dispositions were required,—one for suction, the other for regulating. Both were obtained by two different mechanisms, one of which was eccentric, making an inconvenient projection. Again, the rings pierced for flow of steam easily choked or broke; and the packing was of hemp only. An improvement was then made in the concentric motion. Next an attempt was made to convert the double action into a simple; that is, to produce suction and regulate the flow of water by means of a stop-wheel or lever. Finally, the packing was changed to a stuffing box.

Among the constructions which adopted the stuffing box, that of Del Péche (Fig. 2) is to be mentioned. In this both the pipes P, fixed together, were moved in the stuffing box $a\ a_1$ toward the steam pipe. The constructions in which the double action was changed to a single were introduced by Koch, and by Schaffer and Budenburg. The latter is represented in Fig. 3. The spindle S was fixed, and the steam pipe slid in the

stuffing-box $a\,a_1$. The steam entered at D, and the sliding of the steam pipes was effected by the lever R.

This apparatus had many advantages; but it often happened that the lever set, so that the sliding stopped. Besides, the spring holding the spindle S would slip; and the

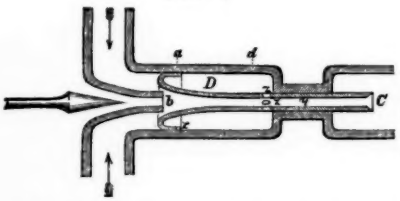
FIG. 3.



division into two parts often caused bending. The plan of fixing the suction-spindle as well as the sliding of the tube R, is due to the firm of Dreyer, Rosenkranz & Droop. Instead of the stuffing-box, is used a simple and lasting piston packing. This injector requires little room, and is adapted to water at a high temperature.

The most ingenious, but also most complicated injector is that of Sellers & Co., of Philadelphia (Fig. 4). There is a suction

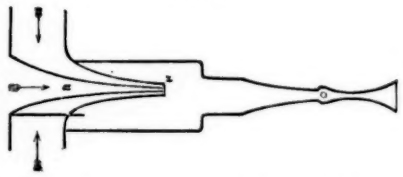
FIG. 4.



spindle, and the pipes b and c are fastened together. The pipe a is provided with a piston x, and the tube c slides in a socket y. If the efflux is too great for the steam tension, the superfluous water escapes through the holes z, and causes a pressure in the space D, which moves the piston back from d to a; if the efflux is too small, there results a rarefaction in D, and the piston moves from a to d until the mixture is regulated.

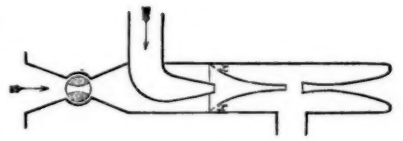
These injectors and many others belong to the class known as suction injectors. To complete the list, we refer to Morton's condenser, and to Körtling's injector. The latter is shown in Fig. 5. In this the steam passed indirectly through a tube a. The pressure was, as a consequence, insufficient; and a certain amount of counter pressure was imposed upon the machine due to the relative narrowness of the pipe at its opening. As the apparatus in this condition could not do its proper work, steam was supplied directly through the ring-formed opening at z, which acted at the same time as exhaust upon the steam cylinder. We regard the supposed performance of this apparatus as illusory.

FIG. 5.



With the appearance of Krauss' injector in 1864 (Fig. 6), which gave the pipes a fixed and stable position, and regulated the flow of water by means of a cock, the apparatus entered upon a new career of development and simplification, which made it so

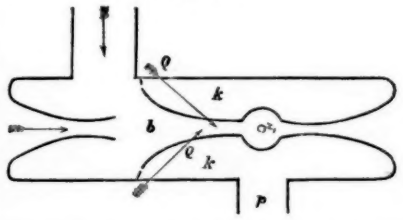
FIG 6.



well adapted for use in locomotives. But in this injector the feed water flowing through the pipe attained too high a temperature.

Schau's injector was next in order (Fig. 7). In this the dimensions of pipes were well adjusted; and by means of an opening at $x\,x$ (Figs. 6 and 7), the suction of the stream

FIG. 7.

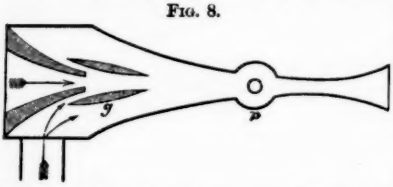


was utilized. After the opening of the water valve K was entirely full of water, and a part was taken up through $x_1\,x_1$. Hence, the same work was got as is given by other injectors of greater dimensions. It was possible to use water at 30 deg. R. and upward. The attempt to get still warmer water led to many experiments, which final-

ly resulted in the perforation of the pipe *b* in the direction of the arrowhead. This gave a temperature of 37 deg. R.

In Friedmann's injector (Fig. 8), instead

FIG. 8.



of the opening at $x x$, a communicating tube g was introduced and x_1 x_1 was dispensed with. At B both Schau and Friedmann supplied their injectors with a discharge valve, having for object, to dispose of the surplus water.

A few words in conclusion. The question is often asked whether water can be supplied to a suction injector, and what the consequence would be. It could not be otherwise than favorable; for the performance would be increased, or the injector would supply warmer water, because the introduction of a large quantity of warm, or of a small quantity of cold water, has the same effect on condensation.

Again, it is asked whether the ordinary non-suction injector may not be applied to suction. This is easily done if the injector is first put in action by introducing water. A suction tube with bottom valve would accomplish this. It would be worth while to give especial thought to inventing some apparatus for this purpose.

The water pressure should not approximate that of the steam, for this would destroy the action of the injector. The water of condensation standing in a steam pipe often hinders the action; and it should be removed so that the steam may pass through without obstruction.

THE ASPHALTS.

From "Journal of the Society of Arts."

Dr. L. Meyn, of Halle, has recently published an account of this new and highly important material, which is recognized as the most complete and impartial hitherto given. The following is a translation of a part of the pamphlet:—

To prevent misunderstanding, he says, it may be as well to state, that when we speak of asphalt stone, we mean the natural asphalt, or porous limestone, saturated with bitumen or mineral tar, which is capable of being worked to a tough, hard mastic—not the raw bitumen itself, which is frequently called asphalt by mineralogists, nor the various artificial compositions which go by that name, but have widely different properties.

The use of the true asphalt is not mentioned in any technical treatises, except in the pamphlets issued by the asphalt companies, and the valuable manuals on building materials written by Bernhard Grübner, architect, and professor of architecture at Berlin, and by Rudolph Gottgetren, architect, and professor at the Polytechnic School at Munich; and even in these works only three of 300 pages of the former, and seven of 668 pages of the latter, deal with the subject, and, moreover, dwell more on the artificial than on the natural asphalt. Some confusion must also be caused in the minds of the readers by the authors regarding the raw bitumen (which is called "asphalt" sometimes by mineralogists) as identical with asphalt stone. The subject will never be properly understood until the artificial mixtures of bitumen with other materials receive their proper name of "mastics," and that substance only which is prepared from natural bitumen and bituminous stones melted together is called asphalt mastic. We shall therefore follow the example of the distinguished engineer Léon Malo, who prefaces his work on "Asphalt," in the "Annales des Ponts-et-Chaussées," 1861, by a classification of these different natural products. We differ, however, from him on several important points, and especially we consider him to be mistaken in including coal and bituminous slate among the asphalts.

Coal belongs, it is true, as does asphalt, to the small group of combustible minerals, but does not belong to the bituminous substances any more than peat or bituminous slate, which usually only becomes so by distillation. Coal and peat form a class by themselves, being produced by an accumulation of organisms which still retain in part their external form and even their internal

structure, by which feature they may be distinguished from those substances which, though resembling coal in many respects, have arisen from organic fluids.

We may dismiss at once, as a merely accidental resemblance, the fact that some kinds of coal—those more especially which are used for the manufacture of coke and gas—may be melted, as this so-called melting is, in fact, disintegration, and cannot be repeated.

It is, however, extremely difficult to distinguish between that kind of coal called jet, which is found in some of the recent geological formations, and some of the pure, hard, bituminous substances, on account of the absence of structural forms; but still, cases like that at Bentheim are very rare, when it is doubtful if the substance to be worked is bitumen or coal, and then it may be generally decided by the geological position.

The analysis of the various asphalt minerals prove them to be oxidized forms of petroleum or naphtha. Their presence, therefore, pre-supposes that of petroleum, or, rather, they consist of petroleum which has absorbed a certain quantity of oxygen.

After these observations, the following classification of bitumens and bituminous stones will be intelligible. We need only mention that paraffine and the crystallized carbonates, though belonging to the same class, have not been included in the list, because of their comparative scarcity.

The pure bituminous substances are as follows:—

1. Naphtha, or rock oil.
2. Petroleum.
3. Mineral tar, or maltha.
4. Mineral pitch, or asphalt.

Naphtha (formerly called rock oil by apothecaries), an almost colorless fluid, with a bluish opal tint, and volatile at a temperature far below the boiling point of water, is evidently the source of all other bitumens, in all of which it may be detected in the first stages of distillation. It is very rarely found in its pure state, except in the regions about the Caspian Sea. Usually it occurs in the crevices and interstices of porous stone, into which it has been condensed after the heat of the earth's surface has distilled it from the rocks which contained it.

At first it was believed that naphtha was produced by the distillation of deeply-buried coals; but eventually the oil springs discovered underneath the coal formation led to the opinion that it was principally distilled from the animal organisms scattered through the rocks—in fact, the remains of countless ages of different animals. On this point, however, there are so many different opinions that it is unnecessary to enter further into it.

On being exposed to the air, naphtha undergoes a material change; it assumes a brown color, with a green tinge, gains in specific gravity, is less liquid and less volatile at a low temperature, and when evaporated, leaves a tough pitchy residuum, containing a small proportion of fine earthy matter. It is then called petroleum.

The various sources of petroleum need not be enumerated here, as they are well known. When it has been for long exposed to the air, it is converted into maltha, or tar, though it is very difficult to draw a line between these two substances.

Wherever a petroleum spring has emerged from the ground for any length of time, maltha or tar will be found near the surface, owing to the oxidization of the oil from exposure to the air. The springs may, in fact, be traced by the existence of the tar. Tar is almost invariably found impregnating a sandy stratum, very rarely in a pure state. A spring of tar has been discovered, however, in the old volcanic region about Clermont Ferrand, in France, which is rich in naphtha and tar in the sandstone rocks. As a rule, however, the oxidization of the petroleum has only been completed in the sand and loose sandstone, through the interstices of which the air can gain access to the oil.

Thus, at most of the sources of petroleum, tar may be found in the sand. At Hölle (in Ditmarschen), over an immense bed of petroleum there is a layer of light diluvial sand, satured with tear, 20 ft. deep, which may be cut like cheese. Also in the sand about the Hanoverian petroleum springs, in a part of the tertiary sandstone at Schwabweiler and Rechelbronn, in Alsace; at Seyssel, in the department of l'Ain; and at Bastennes, in the department of Landes (a region which bears a strong resemblance to the Lüneberg heath). The sand on the heath is bituminous, and for some time, tar was extracted for commercial purposes in the following manner:—

The sand is washed or boiled in water; when the tar rises to the surface it is skimmed off, and heated again, to expel any remaining water. According to its degree

of toughness, it is then either heated in an open cauldron, to drive out the volatile oil, or else distilled in retorts, in order to preserve the oil. The residuum is a hard, black, shining substance of unexampled toughness, which is the asphalt or mineral pitch, the most important ingredient in the manufacture of asphalt stone, being the vehicle by which it is dissolved into asphalt mastic.

The asphalt stone consists of limestone, saturated (in the same way as the sand) with tar, the character of which differs only from that found in sand in appearing somewhat tougher; this may arise, however, from the fact that in the sand the tar covers only the separable grains, whilst in the limestone the smallest interstices are so completely filled, and the two substances so completely united, that heat and water are alike powerless to separate them.

Nature has, however, rarely produced this substance, which is so valuable for industrial purposes. It is found in the greatest abundance and perfection in the Jurassic limestone in the Val de Travers, at Pyrimont, near Seyssel, on the Rhone, and the neighboring localities, Volant and Chavaroche, where it is obtained by mining. In the same category may be included the bituminous limestone of the Alpine Lias mountains, near Seefield, in Tyrol, the tertiary freshwater limestone of Lobsan, in Alsace; also the yellowish-white Jurassic limestone on the Dalmatic island of Brazza, whose dolomitic banks are saturated with 7 to 8 per cent. of bitumen to a depth of 12 ft., so that it might be quarried.

The most important discovery of the kind in Europe is that at Hölle, near Heide, in Ditmarschen, of a bituminous limestone 1,000 ft. in extent, in which the bitumen is as closely united with the limestone as is the case in that of the Val de Travers or Seyssel, but contains, according to the opinion of the Paris Asphalt Company, too much pure petroleum for direct application (owing to its position under 120 ft. of diluvial soil). It is, however, hoped either that by exposure to the air, part of the petroleum will be lost, and part so far oxidized as to produce a perfect asphalt stone, or that on further investigation some limestone may be found containing a larger proportion of tar and less petroleum, or that some means may be discovered of extracting a part of the petroleum.

From this tar, or maltha, and its combinations, we come at last to the asphalt of mineralogists, or pitch, which contains various different ingredients, some hard and brittle, others tough and soft, quite pure, or mixed with earthy matter. It is found in its purest form in the interstices of the older rocks, into which it has been distilled drop by drop, or somewhat less pure in clefts of the rock, as for example in the chalk formation near Munster. It is rarely found in such quantities as Klaproth describes in Avlona, in Albania, or as the pitch lake of Trinidad. The existence of asphalt in the Dead Sea is a fact for which we have to rely on the hearsay report of travellers, rather than on direct scientific observation. The tradition originated with the Greek and Roman writers, who asserted that the asphalt floated about islands in the Dead Sea; and in later ages the Biblical narrative of Sodom and Gomorrah has strengthened the impression. The American naturalists who have examined the locality find, however, that these descriptions do not hold good in the present day; that only in the long intervals between earthquakes asphalt occasionally oozes out of the ground and is washed ashore. This Oriental asphalt, or "Jew's pitch," though invaluable for the manufacture of certain varnishes, is too costly, as well as too brittle, for building purposes. The pitch lake at Trinidad is of more practical importance. On this island, situated opposite the mouth of the Orinoco, there may be seen in the midst of the most luxurious vegetation a lake of the pitch, which flows out like streams of lava into the sea, and forms promontories and reefs. On the edge of this lake, the asphalt is thoroughly hardened by oxidization and the gradual evaporation of its oily ingredients under the rays of the burning sun; towards the middle, however, the sun still has power to soften it, and it can only be crossed on foot in the rainy season.

A considerable quantity of asphalt is exported from the Island of Cuba, under the name of "Chapapote," or "Mexican asphalt," the sources of which are little known. The best Chapapote asphalt contains (like that of Trinidad) 27 per cent. of earthy matter, and the inferior kinds as much as 35 per cent. Under the same name, and from the same regions, a remarkably pure, tough, semi-fluid tar is sent over to Europe.

For all practical purposes, we are therefore restricted to a small number of sources, for we leave the bituminous slate out of the

question, as in it the formation of the bitumen is not always completed.

Having examined the properties and classification of the natural bitumens, we proceed to the history of the asphalt as an article of industry.

We learn from the ancient authors that Babylon was partly built with asphalt, and from modern authors that an asphalt mortar was used for the walls of Nineveh. That used at Babylon was prepared with tar found near Is, on a tributary of the Euphrates.

Eirinus, a Greek physician, was the first to make known in Europe the advantages of asphalt as a building material, in 1712, and he also discovered the existence of tar in Alsace in 1737. When visiting the Val de Travers (the chief valley running up into the Jura from the lake of Neufchâtel) on an official mission from the Bernese Government, in 1711, he met a German adventurer, named Jost, who, with some of his countrymen, had blasted some of the soft, tough, combustible rocks on the sides of the valley, and, finding them worthless as fuel, were trying in vain to find a use for them, Eirinus, who was interested in the subject, examined the rocky sides of the valley, and found that the same soft oily rocks protruded everywhere; he also discovered a rich bed in the neighborhood of Blois de Croix, and comprehended at once its probable use and value.

He applied to the King of Prussia (under whose protection Neufchâtel was at that time) for a monopoly of all asphalt beds which he might discover in the principality of Neufchâtel. After due and careful inquiry, the king granted the request, and this concession was the origin of the asphalt trade.

In 1712, Eirinus commenced his works and experiments, and was able to interest several sagacious and influential men in his undertaking, and to induce them to place various works under his direction to be executed in asphalt, the success of which brought the material into general notice and favor. He published his experiences and discoveries in various small pamphlets, which appeared in 1721, the title of one of which is, "Dissertation sur l'Asphalte, ou ancien Ciment naturel, découvert depuis quelques années au Val de Travers, dans le Comté de Neufchâtel, parle Sieur E. d'Eirinus, Professeur Grec et Docteur en Medecine; avec la manière de l'Employer, tant sur la pierre qui sur le bois." We cannot do better than quote his own words on the preparation of the Val de Travers asphalt:—

"The author, who, on his long and numerous journeys, has had extensive opportunities of pursuing the study of minerals, has received from several reigning sovereigns, but especially from H. M. the King of Prussia, very favorable concessions for the working of any quarries he might discover in the domain of the said sovereigns; and having discovered in the Val de Travers, in the principality of Neufchâtel, a bed of asphalt, quite equal in quality to that of Babylon or the Valley of Siddim, which is well known to the learned, he thinks it desirable to make its properties and advantages better known to the public in the following pages:—

"Being of a greasy, soft, clayey consistency, tougher and more adhesive than pitch, asphalt resists the influence of cold and water to such an extent as to be peculiarly suitable for covering all kinds of constructions; to protect wood and stonework against decay, worms, and the ravages of time, for it renders it almost indestructible, even when exposed to wind, wet, and extreme variations of temperature, as has been practically proved in various parts of Burgundy, Neufchâtel, and Switzerland.

"The preparation of this cement is very easy. The stone must be slightly warmed till it can be coarsely powdered; a small quantity of pitch is added, to make it thinner and more soluble, then the whole is melted over a slow charcoal fire. The surface on which the asphalt is to be applied must be perfectly dry and slightly warmed, and rather more pitch must be added if used for wood than for stone, in which latter case the proportions are 10 lbs. of asphalt to 1 lb. of pitch. If the cement is required to be more fluid, more pitch must be added. If rosin is used, the asphalt will be harder, and offer more resistance to the sun's rays, but the pitch makes it tougher. The asphalt may be smoothed afterwards with a warm iron. Great care must be taken that the surface on which it is to be spread is perfectly clean, otherwise defects will be found in the work, which are not due to the material but to the mode of application If, owing to the frothing of the asphalt during the preparation, any bubbles should be formed, all unevennesses may be removed by rubbing a little cold tallow on the part,

and then passing a hot iron bar once or twice over it."

Eirinus followed up these publications by official documents, in the years 1716 to 1719, in which he states, that between the years 1714 to 1716, in numerous cisterns and wells, the wood and stonework has been successfully joined and covered with asphalt; also, that a platform and a warehouse have been paved, to the perfect satisfaction of the owners. He also mentions that at Basle he joined together, with the asphalt cement, two pieces of solid rock, which were subsequently thrown from an upper story on to the street below without separating again, and he gives other instances of a similar kind.

These facts will not surprise any one acquainted with the works which have since been executed in the asphalt.

To what perfection Eirinus and his pupils carried the working of their new material, is shown by a notice of the engineer, Henri Fournel, who mentions that in the house of a M. Coulin, in Couvet, one of the lovely villages of the Val de Travers, he found a flight of steps—which dates from this period—in which all the upper steps, which are of stone, are worn into holes; while the lower steps, which have been, of course, most used, being coated with asphalt, are almost entirely unimpaired.

Like other inventors, Eirinus was not to benefit by the discovery which restored to the world a building material that had been lost for 4,000 years. M. de la Sablonière, Treasurer of the Swiss Confederation, put himself in communication with him, in order to extend the undertaking, and on achieving his object, he neglected the originator, allowed himself to be regarded as the inventor, and reaped the profits, obtaining, on the 21st of February, 1720, a ten years' monopoly of the Val de Travers asphalt in France, and exemption from duties and tolls.

Buffon mentions in his "Natural History," that the basin of the large fountain in the Jardin des Plantes was covered with asphalt, and he was fully satisfied of its durability, as it was still water-tight after a lapse of thirty six years. As this work was executed in 1743, the Val de Travers asphalt must have been still in request; but gradually it seems to have fallen into disuse, for, in the year 1735, Eirinus had left the Val de Travers, and settled in Alsace, where, living in retirement, he discovered the asphalt at Lobsan. The quarries of the Val de Travers fell into private hands, who worked them more and more exclusively for the oil which was distilled from the asphalt, of which Eirinus also had taught the medicinal and commercial value; and so it happened that, at the beginning of the present century, the invention and the inventor were equally forgotten.

In the year 1802, asphalt stone was discovered at Seyssel, near Geneva. In the sandstone formation, which extends throughout that part of the valley of the Rhone where it forms the boundary between France and Savoy, bitumen is found, scattered in "pots," as it were, according to the consistency of the sandstone strata, which are almost perpendicular, and rise in places to a height of 200 to 300 metres above the level of the river. In the beginning of the present century, the unrepaying process, which had been carried on for some time, of extracting the tar from the sandstone, was suddenly superseded by the discovery of a bed of limestone, saturated with ten per cent. of tar, which, though apparently occupying a limited area, seemed to promise a rich supply for industrial purposes. The idea was started anew of preparing mastic out of powdered bituminous limestone, mixed with five to ten per cent. of tar, and was given out as an original discovery, all the previous experiments in that material having fallen into oblivion. But instead of using it for the simpler purposes to which Eirinus had confined himself, the new discoverers were led away, by the adaptability of the asphalt, to promote its use for many purposes for which it was quite unfitted; hence the popularity which it first attained was succeeded by a reaction, and the Seyssel asphalt was eventually spoken of with as much contempt as it had been received with enthusiasm.

This mistaken application of the material led to a long series of failures, which ended with the complete ruin of the company, and the purchase of the quarries and works by Count Sassenay, in the year 1832, who had satisfied himself, by careful observation, that, under proper management, there was a great future in store for the asphalt, of which he must be looked upon as the second founder; his name, therefore, may be coupled with that of the Greek Doctor Eirinus.

The Count at once perceived that the cause of the failure of the works had been that the material was used for constructions

for which it was unsuited, and which were executed at a distance, by unskilled workmen, whose mistakes were laid to the charge of the asphalt, and he bent all his energies to remedy these errors of management. He ascertained practically what were the purposes for which the asphalt could be best employed, and improved several of the processes, and, in consequence of his experience, he devoted himself exclusively to producing a continuous and homogeneous material, which was made in blocks, and also the tar necessary to melt it. He established an *atelier* for the instruction of workmen in the best methods of working and applying the asphalt, and no government works were executed except under the direction of these skilled artisans. He was rewarded for his care; in a few years the asphalt regained its former reputation; market-places and public buildings were paved with it, and in all the French fortresses the stonework was protected against the damp by a coating of asphalt. The celebrated footpath of the Pont Royale, the fine pavement of the Place de la Concorde, at Paris, as well as many pavements at Lyons, and covering of the casemates and corridors of the Fort of Vincennes, date from that period.

At Seyssel, mineral tar was first substituted for common pitch (which Eirinus had used), an improvement brought about by the circumstance that tar was found in the same neighborhood as the asphalt stone. Another improvement was the addition of some of the coarse sand found in the bed of the Rhone, which gave additional hardness and solidity to the asphalt mastic. An addition of one-tenth or even one-fifth of coarse sand, besides improving the consistency, rendered the material much cheaper, especially at a distance, where the costs of transport were such a serious item in the expense.

It was found also, that for public footpaths, a sprinkling of coarse sand on the surface, firmly melted up with the asphalt, rendered it stronger, and enabled it to offer greater resistance to the constant wear of the traffic.

The asphalt was used in most of the large cities of Europe and the United States. In St. Petersburg it was used for the pavement of the terrace of the Imperial Palace.

It is of course impossible now to say if all these improvements are entirely due to Count Sassenay. We only know that, on the works coming under his control, the undertaking prospered at Seyssel.

The process of laying down the asphalt footpaths has undergone no material alterations since the days of Eirinus. By the courtesy of the Asphalt Company at Paris, the writer is enabled to give the following details as to the process:

The asphalt must be laid on an even foundation, without any hollows in which water could lodge; any attempt to lay the asphalt on sand, flags, or tiles, has failed, as the unevenness caused it to be worn out more rapidly in some parts than in others. An even layer of concrete is the most economical and reliable foundation. The concrete must be perfectly dry before the asphalt is poured on, otherwise the steam generated by the superfluous moisture will produce bubbles and holes; also the concrete will not harden if it is covered too soon.

The mastic is sent from the works in blocks of about 25 kilos. They are broken up into pieces, about the size of the stones on macadamized roads, and melted in cauldrons with about half the total quantity of bitumen, which is to be added eventually (about 5 or 6 per cent. of the weight of the mastic). One quarter is kept to be added at discretion, if the mastic appears too dry, and the last quarter is added with any fresh supply of asphalt. The temperature is kept up to over 150 deg., and under 170 deg. Celsius. When the mastic is thoroughly melted and stirred up, the molten mass in the cauldron is covered up and kept over the fire, and half of the sand is added first. without stirring, as it sinks to the bottom by its own weight. This is the only way in which the sand can be added without chilling the interior of the mastic. Then the second half of the sand is added in the same manner. At this point it may be seen if the mass is sufficiently bituminous, or if the remainder of the tar is required. When the whole mixture is ready, and has been brought up to the required temperature (which may be easily seen, by any water dropped on the surface being immediately carried off in steam, while the ladle can be plunged in and withdrawn without any particle adhering), it may be applied to the surface which is to be covered, stirred all the time lest the sand should all sink to the bottom.

The mastic is laid on with a wooden trowel, of peculiar form, which is first

thoroughly warmed, lest the mastic should adhere to it. At the various joinings the asphalt must be poured on with large ladles, in order to unite the surfaces effectually, which are never properly joined without this precaution, too often neglected. A slight and rapid pressure is then applied to smooth the surface.

Too often the asphalt receives after this only a slight scattering of sand, it being thought that it serves only to roughen the asphalt. But this is not the chief purpose of this part of the process, as the sand is to supply the place of that which sinks down, and thus leaves the surface soft and liable to melt under the rays of the sun. The workmen should therefore scatter sand plentifully, and stamp it down quite equally on all parts. The footpaths at Paris are covered with a layer of asphalt, 6 in. in depth, and 3 kilos. of bitumen, with 30 kilos. of washed, dried, and sifted sand allowed to 46 kilos of the mastic.

Formerly, the asphalt was mixed and prepared in cauldrons, with portable iron stoves, on the spot where it was to be laid down; this was found, however, to be an inconvenient obstruction to the street traffic, so the plan was adopted of preparing the asphalt in the works, and bringing it in the cauldrons into the street.

It is difficult to ascertain exactly how long an asphalt pavement, executed on the best principles, and with good materials, will last; but 40 years' experience in Paris and Lyons points to about 20 to 25 years, if it is from 6 to 8 in. thick.

In consequence of the immense demand for asphalt, similar works were successfully set on foot, in 1838, by the Brothers Dournay, at Bechelbronn, in Alsace, a locality which was well known to abound in bitumen (as had been discovered by Eirinus), and where a bed of bituminous limestone was brought to light.

About this time the long-forgotten asphalt-beds in the Val de Travers came before the notice of Count Sassenay, who had given over the works at Seyssel into the hands of a company. He speaks of them as follows: "When my attention was first directed to the specimens of the asphalt of the Val de Travers, I could hardly believe that they were not taken from the best part of the Seyssel quarries, so complete was their similarity. I did not, however, venture to embark in any undertaking without making due inquiries. Accompanied by the able engineer, Henri Fournel, I investigated thoroughly the geological formation of the Val de Travers, and satisfied myself that it contained a very rich bed of asphalt stone, similar to that of Seyssel, only of a finer texture, and containing 2 per cent. more bitumen, which is a valuable quality, as it saves the necessity for adding that amount of tar. The asphalt limestone extends uninterruptedly along both sides of the valley, and on beholding the enormous masses which mark the course of the Reuss, to the right and to the left, one cannot conceive how such a supply could be exhausted."

Count Sassenay succeeded in purchasing the monopoly, and established a large company at Paris. Thus the three great asphalt companies of the Val de Travers, Seyssel, and Bechelbronn (or Lobsan) were instituted by French enterprise.

Notwithstanding the high estimation in which the asphalt was held, the municipal authorities in large and distant towns hesitated to pave all the footpaths with a material which, owing to the immense cost of transport, could not be otherwise than expensive, in spite of the competition between the three companies. The high price not only hindered the general adoption of the asphalt, but offered such a temptation to adulteration that many spurious imitations were brought out under that name, the failure of which impaired the reputation of the genuine article.

It has been found impossible to produce artificially the close union between the limestone and the tar, even if chalk or porous limestone is boiled up with pure mineral tar, and then treated like the natural asphalt stone, in which case a substance is obtained which resembles the latter in appearance, and even in smell, but is proved to be not nearly as durable. In the natural asphalt, the limestone has been evidently in the first instance saturated with petroleum, which, in the course of ages, has been oxidized in the interstices of the stone; hence the two substances are as closely united as is possible without chemical combination, and the sun or the cold only affects the very thinnest crust on the immediate surface.

With the extension of the railways, and consequent diminution of the cost of transport, the true asphalt was restored to its proper use, at least for large works, and enabled, to a certain extent, to drive the artificial imitations out of the field.

In the year 1843, a bed of asphalt stone, similar to those of the Val de Travers and of Seyssel, was discovered at Limmer, near the town of Hanover; and Herr Hemming established similar works with such success that the Limmer asphalt was considered worthy to be classed with that of the above named localities; indeed, in the first London Exhibition superiority was assigned to the German asphalt over that of the older companies. The broad foot pavements of the streets of the town of Hanover bear witness to its excellence. The fact that the mountains which border the great German plain extending through the district of Hanover are rich in bitumen and mineral tar, gave great facility to the asphalt works at Limmer.

When, however, the granite or tile foot-pavements were gradually substituted for the asphalt, as, for example, at Berlin, it became necessary to seek some other means of employing the asphalt. The solution of the problem was found in the paving of the streets in large towns, a work requiring unlimited quantities of the material, which the railways now placed within reach.

The experiment was tried of laying down broken freestone on a bed of sand, and filling up the interstices with molten asphalt mastic. It proved unsuccessful, however, for when cold the mastic was too brittle for the purpose; and if the wheels of the carriages struck against and broke one of the corners of the stones, a hole was formed, which gradually widened and was very difficult to mend. In Lyons 10,000 cubic metres of roadway were covered with a layer of asphalt about 2 in. in depth, upon a substratum of concrete of about 4 in., and this was found to answer admirably, but was so costly that in other towns the municipalities were obliged to content themselves with covering in that way the places where the most crowded thoroughfares crossed, and the spaces in front of public buildings, where it was important to deaden the noise of the traffic. In these cases it was found desirable to furrow the surface, to prevent accident to the horses, which were never long enough on the asphalt to get used to the change from the rougher roads; but in Lyons, where the asphalt is more general, this precaution has been found unnecessary. At Vienna the great Aspern-bridge has been covered with a double layer of asphalt (from Seefeld, in Tyrol), the lower part more elastic, the upper harder. It was not considered necessary to furrow the surface, and there has not been any increase in the number of accidents to horses in consequence.

The Limmer asphalt seems particularly suitable for this purpose, being rather softer and more oily than that of Switzerland or Savoy. In the heat of the summer it receives the impression of the carriage wheels, and for this reason it has always been found necessary to mix with it some of the dryer asphalt of Vorwohle for the foot pavements.

A solid foundation is first prepared with mortar, which is covered with a layer of coarse asphalt 2 in. thick and containing 10 per cent. of tar, and beaten down till it is quite hard; then a layer, 1 in. thick, of asphalt, consisting of 75 per cent. of mastic, 3 per cent. tar, and 22 per cent. of coarse sand.

A similar kind of composition was used in Hanover for the flooring of the cavalry stables, the saving in straw, cleanliness, and freedom from smell being found to be a great advantage.

But even this kind of road was so expensive that the municipal authorities were forced to look about for some other method, as none of the old pavements were at all efficient, with the constantly increasing street traffic. In paved roads, the single stones were apt to be displaced, the edges chipped off, and the interstices widened, so that the dirt of the street could lodge in them and become the source of noxious miasma. The macadamized roads (adopted, it is said, in Paris, to prevent the erection of barricades) were still worse, causing a sea of mud in wet weather and a cloud of dust when dry. Asphalt was thus the best resource, and at last they hit upon the right method of applying it, a method indicated by the nature and properties of the stone, which is so soft that in the quarries the hole for the blasting can be made with a carpenter's gimlet, and the asphalt can be cut into shavings with a pocket-knife. This property gives great trouble in working it during the summer, as the hammer frequently flattens the stone instead of breaking it, and in very hot weather even blasting is powerless unless done with nitroglycerine; while in winter the blows of the hammer sound muffled, as if striking a soft block of gypsum.

From this peculiarity it was inferred that the asphalt was admirably qualified to be beaten down into a pavement; and this

opinion was confirmed by the state of the roads and paths in the quarries of the Val de Travers itself, on which the small pieces falling from the carts were constantly pressed down and flattened by the cart-wheels passing and re-passing, till they at last formed a firm, solid, elastic surface, on which the horses could drag their loads with great ease, and which did not seem to be worn out by the traffic. The author noticed these roads in 1856, without knowing that this plan was so soon to be applied to the streets of towns. M. Henri Coulaine put this idea into practice in the department of the Maine et Loire, and described the result in the "Annales des Ponts-et-Chaussées."

(To be continued.)

AN AMERICAN'S VIEW OF THE TIN MINES OF CORNWALL.

From the "London Mining Journal."

A visit to the tin mines of Cornwall by an American interested in mining affairs is a labor of love, undertaken with the highest anticipations—mines wrought anterior to the Roman invasion, the chief deposit of a metal longest known to man, furnishing to the commerce of the world 10,000 tons annually. Tradition and modern fact unite here in furnishing a Mecca for the miner. In addition to this, the Cornish expert has gained a world-wide reputation, causing him to be accepted as the surest reliance for works of exploitation wherever discovery opens new fields for mining enterprise. The four great forces commonly used in operative mining—the handicraft in extraction, the engine, the pump, and the crusher—have each gained distinctive celebrity by a Cornish paternity. Every text-book and treatise on mining economics illustrate theories by citing Cornish practice, and furnish examples of results sanctified by ages of Cornish experience. As Swansea has become the focal of authority in the work of reduction, so, too, has Cornwall established high reputation in the work of production.

From London a rich country is traversed 328 miles to Penzance, and many cities passed, all noted for wealth, commerce, and large populations. The railway from Exeter to Devonport and beyond exhibits the grandest achievements of brain and capital. Here rocky slopes are walled up and girdled, precipitous cliffs subdued; there the bastion flanks of mountains self-fortified against the battering assaults of ponderous waves, are penetrated, and the ocean itself driven back, or the blows of its powerful battery deadened short of their destructive aim. Every train may be likened to a triumphant procession, cheerfully recognized by the clattering echoes from mountain gorge and rocky embattlements, and acknowledged, too, more sullenly by the surging waves, as they break harmless and crest-fallen against abutment walls.

The landscape is a varied panorama of water, hill, and valley, garden fields and primitive forests; the latter now civilized into splendid parks, famous as dukedoms and earl domains, turreted castles, and linked with the history of a thousand years of human progress. The eye that a moment since had gazed upon the turbulent ocean, the bridged estuary, and placid bay, where ships rode at anchor, and fishing boats gathered in the spoils of a thrifty net, now ranges over a pastoral mosaic, luxuriant plots fringed with vegetating walls of stone, and traversed by winding streams, gleaming brightly through marginal bushes and stately trees; within them here a lazy flock of sheep, all fatalists, seemingly content to fatten for mutton-chops and woolly fleece, a short-lived peaceful browsing being their lot; there a more sprightly herd of cattle, proud of their breed, and would be more defiant did they know the fate of their sirloin, hide, and tallow; near by, a bevy of horses, ready to scent a frolic in the air, enjoy a sham contest on the sod, and seemingly wise enough to forecast triumphs on the course, changing sovereigns by leaps or speed, or by drafting the commerce of the world. So on to Cornwall, where the hills are more lofty, the valleys more pinched, and the landscape crowded with huge piles of rock, strange to the surface, or high mounds of debris brought up with the embowelled wealth of subterranean drifts. Here a Cornish engine, enclosed in walls, monumental as if of a fistic contest, the index finger pointing upwards; there the winding-wheel and lofty gear, below the iron skeleton and ponderous hammers, which rise and fall in turbulent battery, the clattering

din of mining thrift and metalliferous wealth.

Thus Penzance is reached—a silent, steadfast, sturdy town, built as if to challenge endurance with the adjacent hills—a solid town and a steady-going people, who are best known to the distant world as dwellers near the "Land's End," hence *ne plus ultra*ites, never laughing unless tickled with Cornish straws, and won't sneeze unless aggravated by Cornish snuff. The surroundings are picturesque, even magnificent, three-fourths encircled by the ocean, granting a stretch of view grand and imposing, whilst on the land there are garden plots and thrifty fields redeemed from barren wastes of rocks and stones which have been economized in fencing, sodded and moss-grown on the coping. Residences there are which bespeak the wealth obtained from the adjacent mines.

A ride of seven miles over a thoroughly good road brings you to St. Just—a parochial district and a mining centre. The houses of the work-people, the offices of superintendents and agents, have the solemn, solid air of comfort and stability, fixed, finished, and unalterable. All else, on first view, seems a ruin and a wreck—machinery without a roof, hoisting gear without cover, shaft-houses looking as if extemporized after a hurricane which left none but broken posts and shattered boards—all out of doors cheerless, unpromising, only showing life by a ricketty clatter of stamps, the rattle of stones and sludge from skips, shot down from infirm galleries—these attended by slow-moving men stiffened by exposure, drenched by rain, and working as if it had to be done rather than that it ought to be. This was the Cornish Mecca of my imagination.

THE BOSCASWELL DOWNS MINE.

Possessing a letter of introduction to the managing agent, Mr. Williams, I was kindly permitted to enter the mine and go over all the works of the Company, and very cheerfully furnished all facts and information valuable to a stranger. In the same district are located the old and celebrated Royal mine of Botallack, The Levant, North Levant, St. Just Amalgamated, St. Just United, Balleswidden, and others. The Boscaswell is among the most ancient and most extensively worked. The deepest shaft is over 200 fms.—1200 ft. Some 20 levels have been run, some to the extent of half a mile. Active operations have been carried on over 100 years. The profits of a modern period reach the sum of £300,000. Several spurs have been slightly followed, which indicated valuable deposits of metal; parallel courses, or lodes, have also been found and prospected from the surface; these have proved rich enough to warrant cross-cuts from the deeper levels in the main lode, which will speedily develop those that prove valuable. The upper works consist mainly of one Cornish pumping-engine, two stamp-mill engines, each running 36 stamp-heads, and three winding-engines, two of which are of modern construction—the portable engines manufactured by Messrs. Robey & Co., of Lincoln. There are upwards of 300 men employed underground and on the surface. Nearly all the underground work is set at either tribute or contract, also a considerable portion of the surface work. The day workers are supervised by the agents. There are also two tin-washing buildings, and the multifarious apparatus and fixtures for concentrating out the tin-stuff. These are close by the stamping-batteries, and receive the flowing pulp as the rock is crushed.

It would be a superfluous task to enter into any detail of the mine. Its reputation and permanence as a metalliferous lode is quite sufficiently proved by the work of a century, and the production of immense sums of money in the past. The walls solid granite, the crevice seldom 3 ft. (oftener less than 2 ft.), irregular in pitch, a selvage or gouge between the vein deposit and the hanging wall, here and there large bunches of clay-slate, in which the sulphides and arsenides of copper and iron are in association with the tin, and often with wolfram. A very considerable part of the vein matter is decomposed disintegrated slate, silex, and oxide of iron, which when broken down becomes sludge with the dripping water of the mine. In consequence of this rottenness, very little blasting is required, the most yielding to the pick and the gad. The stuff, sent up in skips, is, perhaps, 40 per cent. of sludge to 60 per cent. of firmer material.

The shafts, of which there are three on the main lode (two hoisting and one for the pump), all deep, are without timbering. The simplest and rudest form of ladder-ways serve for ingress and egress, and as rude and as primitive ways, slides, are furnished for the loaded skip. Water

is made in very considerable quantities, and no means provided to prevent dripping from the walls and cross ties of the shaft and ladder-ways. A rain of mud and sludge increases in quantity as you descend.

The hoisting rig is mostly of Cornish sanction, unchangeable by any improvements made elsewhere during the last century. But at the Boscaswell a dreadful innovation has been successfully introduced. A wicked combination of devices, not of Cornish paternity, and in defiance of the scoffs, jeers, lugubrious prophecies, has been introduced, and, *mirabile dictu*, it succeeded—actually brings up a Cornish skip, over a Cornish slide, filled with Cornish ore, which hitherto has only been done by a Cornish engine, just fixed so and so. This audacious contrivance actually dares to consume only one-quarter the amount of coal hitherto required, accomplishing the same work in two-thirds of the time—and "won't bust!" The Cornish engineers, of Cornish infallibility, await *that bust*, intending then to visit the ruins, each carrying a banner—"I told you so!"

The stamp-mill is of Cornish pattern and Cornish arrangement, placed all out of doors, perhaps to harden the *calithumpsian* monstrosity, and induce activity among the attendants, so as to get back to cover from the wind and rain. The ore is dumped into bins behind the battery, and mainly fed by water, since that means is the most irregular, and best suited to the irregularity of the thumpety-thumping it is to get as it passes through the coffers. Ingenuity exhausts itself in keeping the thing in repair. Human muscle and endurance being cheap, coal abundant though dear, water free, and eternity full of time, this contrivance is deemed sufficiently perfect to render all attempts to supplant it by more modern construction one of the "I told you so's."

The washing-floors are mud flats covered with a roof, partially boarded on the sides with large openings not always fitted with doors or windows. Here are buddles, concave and convex, launders innumerable, slime pits and coffers, tossing-tubs and keeves, frames and thumpers, shovels, scrapers, and slush everywhere. Men and women, boys and girls, do the work, and escape insanity because they know nothing but the names of the things and the routine; an attempt to understand the *rationale* of the proceedings would end in dementation. Repetitions, divisions, redoing and undoing, shovelling and reshovelling, putting in and taking out, tossing and "framing," here a little and there a little, *ad infinitum*. The process is something like the chimney conundrum—"Patch upon patch and a hole in the middle," guess what it is? At the end of this labor of Sisyphus—rolling a huge stone up a high hill which ever rolled back again—the tinstuff is finally ready to be sent to smelter.

TIN SMELTING.

There are five smelting establishments in and about Penzance, three of which are owned or controlled by Messrs. T. S. Bolitho and Co. The very obliging manager of one furnished every desired information, and kindly permitted a view of the works. After weighing the tinstuff, brought in long slender bags of about 250 lbs. contents, the product is sampled and assayed for two purposes—the quantity of metal and the quality. Some mines produce tin of a finer, or rather more easily refined into tin of the best quality. Three grades of metal are produced—one for the dyer's use, one for the tin-plate worker, one for common alloyage, such as solder. When the ores are thus classified they are mixed with 1-5th to 1-8th in weight of powdered anthracite, then damped and introduced into the common reverberatory furnace. The coal is said to be used for a flux, whereas the chemical effect is that of abstracting the oxygen from the dioxide of tin speedily at a low heat, whilst a higher heat unites the iron and silica, forming a silicate of iron on the top of the already deposed tin. If the iron is not in sufficient quantity to absorb all of the silica, lime has to be added for the surplus. The fluid impure metal is then run from under the scoria and ladled into large moulds. These blocks are again melted in another furnace at a low temperature, which causes the tin to float upon the heavier impurities, which subside to the bottom. The tin is again run off into moulds. These are then placed in a large cauldron of iron, heated from below; into the liquid metal, green wood is submerged by force. The heat rapidly evolves steam and other gases, causing the liquid mass to bubble and become turbulent with internal commotion, serving to thoroughly mix and cast to the surface all the impurities remaining. When this is sufficiently done the metal is ladled out into moulds, stamped, and piled up for the market. The slag and

scoria are sorted, crushed, and repeatedly washed for metallic tin. The heavy impurities obtained from the bottom of the second furnace are picked over for attached particles of tin, and then sold by weight at a low price per ton. Until lately these blocks were given away for ballasting.

THE TINSTUFF.

The ore when brought to grass contains about an average of 1 per cent. of pure metal to the ton—20 lbs. out of 2,000. The tinstuff as washed and delivered to the smelter is about 33 lbs. to the 2,000, the surplus consisting of oxygen, and the impurities still clinging to the dioxide of tin. The average of £80 per ton is paid for the tinstuff. Hence it will be seen that 100 tons of average ore is worth about £130 as it comes from the mine—26s. per ton=$6.50, The ore is broken by hammers when it falls from the skip, the copper nodules selected out, and the bulk sent on to the stamps. This copper ore, in small quantity, is sold for copper. A portion of the pulp, after first washing, is reserved for roasting for the elimination of the sulphur—a ferric oxide and a cupric sulphate. The latter is mainly wasted. Means are now taken at the Boscaswell to precipitate metallic copper from this sulphate.

PRODUCTION.

The present production of the Boscaswell is from 70 to 80 tons per day, the limit of the crushing capacity. This property has come under the present management during the present year, burthened with all the conditions of the past system of working—the patchwork of a century, the old never abandoned, only added to by a new turn or genuflexion adapted to the fixed order of things. With an incongruous system, exposed machinery, naked shafts, and a higgeldy-piggeldy scatteration of appliances, also came a non-disciplined, demoralized system of labor, accustomed to abuses which had obtained the sanction of habit, hence deemed legitimate. To fracture the crust of stolid conventionalities by the introduction of new machinery and a more disciplined system of labor is no easy undertaking, and never a popular one in a self-opinionated community. When abuses have grown into even criminal practices it is difficult to set up a higher moral standard. This has, however, been commenced in both respects. A new engine, boiler, and winding apparatus now supplies the place of the Cornish pet, at less than two-thirds the cost of plant, and at a saving of about £1 per day, doing the same work in about two-thirds the time. Other innovations in machinery are to follow—modern stamps, and perhaps a remodelling of the washing devices. All to be housed, systemized, and under a careful discipline, precisely as if the workmen were to be considered no longer only as hired beasts needing no shelter, and incapable of appreciating a proper care for their comfort and physical well-being.

That the laborers object to this solicitude in their behalf, accompanied, as it must be, with a change in the correlative abuses which are advantageous only as seen from their stand-point, and are ready to mutiny against self-reformation, as well as economical advancement of an important industry, is no new phenomenon. The traveller who had camped out during a rainy season found that he could not go to sleep unless some kind hand emptied a watering-pot over him, illustrates the force of a habit which demands a continuance of a practice however monstrous. This difficulty has already been discounted by the wise administration of the superintendent, aided in the management of the men by Mr. Silk, who to a clear understanding of the duties required of the laborer adds a wise appreciation of the men with whom he has to deal. To change habits, remove abuses, and set up new modes of action and a new code of morals as between the employer and the employed, and, in the end, retain the esteem of the men, demands a ripe judgment, as well as a true moral courage. What has been done warrants the prediction that a failure will not close the connection of Mr. Silk with the Boscaswell Mine.

It is needless to remark that the progress of the present day demands the employment of the best devised machinery, the closest application of the most intelligent system of manipulation, the highest consideration for the moral and physical well-being of the laborer. The Cornish system ignores every one of these principles, to the great loss of the capitalist, the injury and continued demoralization of the laborer, and, of course, in arrest of all improvement. Should there be no improvement in these respects, in order to lessen waste in labor and material, before the wave of labor reform, demanding less time and higher wages, reaches Land's End, the tin mines of

Cornwall will cease to be remunerative, and will have to be abandoned.

Fortunately, an intelligent management has taken possession of one of the most important mines, and this work of regeneration has already been successfully inaugurated. The continued success of this wise beginning will forearm Cornwall against the inevitable appreciation of labor, before the waste of a false system has been corrected and a higher tone inspired among the laboring classes.

CHANNEL PASSAGE.

From "Engineering."

The improvement in the means of intercourse, and the establishment of better communication between England and France, has been the subject of earnest discussion during many years past, and the public has had presented to it a number of reasonable and unreasonable plans having this object. These plans may be classified under four heads: Those for bridging the Channel between Dover and Calais, or some adjacent point on the French coast; those for making a causeway, and thus creating an artificial isthmus; those for the establishment of a ferry, and, finally, those for driving a tunnel beneath the bed of the sea. Of all these, the first two have never been advocated by any person worthy of consideration, and may be therefore entirely dismissed; the two latter schemes are represented by two eminent engineers, in whose track follow a number of more or less obscure individuals who clamor loudly for the credit of precedence in idea, as vehemently as if they could ever have advanced this question of improved international communication to the stage to which it has been brought.

The representative of the steam ferry is Mr. John Fowler, and that of the tunnel, in this country, is Mr. John Hawkshaw.

We have from time to time so fully laid before our readers the details of the steam ferry project, that we need only allude to it briefly now. By this plan, as it was first laid before Parliament some years since, it was proposed to construct suitable harbors on each coast, between which steam ferries, 450 ft. long and 57 ft. beam, were to run propelled by engines of 1,500-horse power collectively. The transit was to be performed in an hour, and the most complete accommodation was to be afforded for the carriage both of passengers and goods. To this end, railway passenger carriages and wagons were to be taken on board the ferries, so that either in going to or returning from the Continent, no change of vehicles would be necessary either for passengers or freight. The point selected for the English harbor was Dover, and that on the French coast between Cape Grisnez and Boulogne, at a spot possessing many natural advantages for the purpose. A short line of railway would be necessary to connect the French port with the Northern Railway of France, and complete the communication. The total estimated cost was about £2,000,000, and the time required for the execution of the scheme was three years.

Such, in a few words, was the original great project of Mr. Fowler, which, since it was first brought into public notice, has, time after time, with some modification, been laid before Parliament, as well as before the French Government. Circumstances and the force of persistent opposition has hitherto prevented this undertaking from being commenced; but we believe, as we have always stated, that there is no other means by which a perfect intercommunication can be profitably secured, and we feel assured that the Channel ferry scheme will become an accomplished fact. It fulfils, indeed, all the requirements of the situation. For a moderate outlay, considering the magnitude of the work undertaken, a service would be established which would accomplish the crossing rapidly; upon the route chosen by Mr. Fowler, two miles of sea and 14 miles of railway would be saved between London and Paris. The minor advantages incident to through passenger trains between this country and the Continent would be secured, and the inestimable benefit arising from the fact that goods could be transferred without breaking bulk forms one of the most important features of the undertaking. Added to this, the size of the boats, and the speed imparted to them, would insure a comparatively steady deck, even in the worst seas of the Channel.

Turning to the other proposed means of Continental communication—that of a tun-

nel beneath the bed of the Channel—we find that the idea belongs to a past generation, when a Frenchman, with burrowing proclivities, propounded the idea to the first Napoleon, of annexing this country by a tunnel. Considering, however, and justly, that Mr. John Hawkshaw is the representative of this system of communication, we need only turn back for a few years to trace the little that has been done, and the great things proposed in this direction. In 1866, borings near the South Foreland in this country, and near Calais in France were commenced, and continued during two years; the former reached the green sand, after a depth of about 550 ft. had been obtained, but at a less depth the French shaft was stopped by accident. Mr. Hawkshaw also investigated, so far as a preliminary examination would allow, the formation of the Channel bed along the line of the proposed tunnel. These inquiries, tested also by some independent borings, such as the artesian well at Calais, showed that both the lower grey and the upper white chalk, which on this side have a thickness of 295 ft. and 175 ft. respectively, increase gradually towards the French coast, where the thickness of the grey chalk is 480 ft., and that of the white overlying chalk is 270 ft.; it is almost certain, too. that there exists no serious rupture in the strata, while the depth chosen for the invert of the tunnel would probably be below the pernicious influence of any fissures that may exist in the white chalk near the sea bed. It was proposed to lay the level of the rails at a depth of 270 ft. below the bottom of the Channel, to approach and quit the tunnel on each coast with grades of 1 in 60, and to give to the tunnel itself a rising gradient of 1 in 2,640 on each side towards the centre. The total length of the tunnel would be 29½ miles, of which 7½ miles would be taken up in approaches. It was intended that accomodation should be given for a double line of way, and for this purpose the tunnel was to be 28 ft. wide, formed with a semicircular arch 23 ft. in height from the rails; and the thickness of the brickwork, sides as well as invert, was to be 3 ft.

In March, 1869, a report was laid before the Emperor of the French, prepared by the influential Committee appointed to examine into the scheme which had M. Thomé de Gamond as its able representative and exponent in France. This Committee, whilst not hesitating to give their opinion that the work could be executed, although many grave and hidden difficulties would probably beset the path of the engineer in every step of his hazardous undertaking, found great trouble in forming any conclusion as to the possible commercial future of the work, supposing it to be completed. The minimum estimate upon which they based their assumption was £10,000,000, too large a sum by far to sink with the hope of obtaining a profitable return. It was proposed at this time to obtain a Government grant of £2,000,000 (as much as Mr. Fowler's first estimate for his complete ferry scheme), to execute preparatory works. This proposition, however, came to nothing, and the storm, then gathering, which subsequently swept across France, has ended, for many years at least, any probability of extensive Government help from that country for this purpose. We believe, however, that a private company has been formed, with the object of sinking a shaft, and a large amount of capital, and to make headings under the sea. What good this company will ever achieve we don't pretend to understand.

Descending, however, to a much more practical level, Mr. Hawkshaw has recently proposed a means of improvement in our Channel service, which consists in placing a fleet of fast boats to run between Dover and Calais, of a type similar to the Holyhead steamers, 350 ft. in length, and drawing 8 or 9 ft. of water. These would be simply passenger boats, having no accomodation for railway vehicles on board, and requiring but little alterations in the existing harbors to enable them to run from side to side at all times. This proposition, it will be seen, approximates very closely to that of Mr. Fowler, differing only in degree, and involving less outlay, just as it affords inferior accommodation. That the execution of such a suggestion would confer an immense benefit on the travelling public is of course quite evident, and it would be a grand step in the right direction; but such a measure cannot be regarded as solving the problem of international communication with all its extensive requirements.

But all these foregoing projects to which we have alluded are at the present but schemes upon paper, which will have to fight their way through powerful opposition and many difficulties before they are presented to the public in such a form as to draw forth money from the public purse.

Of a totally different character, however, is the last scheme we have to notice, in which Mr. Henry Bessemer and Mr. E. J. Reed are the chief movers, and which, not wanting Parliamentary sanction, will not suffer the long and tedious delays which would otherwise attend its execution. When we say that Mr. Bessemer and Mr. Reed have lent themselves to the development of this undertaking, the capital required for which is but moderate, we think we have said enough to convince our readers that many months will not elapse before an efficient service will enter into competition with the boats at present running between Dover and Calais, and which are as great a disgrace to the country as are our Thames passenger boats, and for the same reason—want of competition. The new boats proposed by Mr. Reed and Mr. Bessemer to run between Dover and Calais will be the same length as those suggested by Mr. Hawkshaw, *i. e.*, 350 ft., but they will draw, when fully loaded, only 7 ft. 6 in. of water. The deck beam will be 45 ft. wide, and the width over the paddle boxes 65 ft. A speed of 20 miles an hour will be obtained from two pairs of engines, developing collectively 4,500 horse power, and driving 4 paddle wheels. The vessels will be double-ended, with a rudder at each end, so that the necessity of turning will be avoided, means being provided to lock the rudders at will. They will be designed with a very low freeboard at each end extending for a distance of 50 ft., so that they may cut through the waves instead of mounting them. The useful length of the vessels will thus be reduced to a length of 250 ft. Speed will rightly be one of the first considerations in designing these boats, because upon such a service as that for which they are intended, quickness of transit is of the greatest necessity. Next to this qualification comes that of accommodation, and in this respect the utmost attention will be paid to the comforts of the passengers. At each end spacious and well-appointed cabins will be provided for the second-class passengers, who will, besides, enjoy ample deck room; but the principal feature, and one for the development of which the boats are specially designed, will be a large central motionless saloon, constructed according to the plan proposed by Mr. Bessemer, and one of the earlier forms of which has already appeared in this journal. This saloon will be placed in the middle of the vessel, 70 ft. long, 30 ft. wide, and 20 ft. in height, fitted with some state-rooms leading off from the main cabin. On top there will be a spacious promenade deck, 7 ft. above the main deck of the vessel. Without describing in detail the means adopted for securing an absence of motion in this saloon, we may mention that it is suspended at each end and at two intermediate points upon steel axes, supported upon standards. The floor of the cabin, necessarily of great weight, is placed below the level of the points of support in order to assist in keeping the saloon steady, and to counterbalance the disturbing action of the top weight due to passengers on the promenade deck, as well as that arising from the action of the wind upon the exposed sides of the cabin, which, however, are partially protected from the action of the wind by the two paddle-boxes placed on each side of the vessel. By the arrangement adopted, the suspended saloon, which will weigh 70 or 80 tons, will always tend to keep in a vertical position, and the oscillations which would arise from the ship's motion, are to be counteracted by simple mechanical appliances. It is only contemplated to neutralize the rolling of the ship, as vessels of so great a length, and of such a form as those to be built for the Channel service, will be subjected to comparatively little pitching, the motion from which will be greatly reduced by the central position of the saloon. To prevent the saloon from being affected by the oscillations of the vessel, or its equilibrium from being disturbed by the movements of the passengers, it is fitted with hydraulic gear, by means of which its position with respect to the vessel is placed under perfect control, an attendant, having a spirit level before him, being enabled, by the manipulation of a single lever, at all times to keep the floor of the saloon horizontal. One arrangement of hydraulic gear devised by Mr. Bessemer for this purpose was illustrated by us on page 100 of our eleventh volume, and we hope in an early number to give engravings of that to be actually fitted to the Channel steamers. Judging from the result obtained by the working model constructed by Mr. Bessemer, there can be very little doubt that the desired amount of steadiness can be imparted to the saloon in actual practice, for although this model conveys no idea of the motion of a ship in a seaway, the extreme and rapid oscillations imparted to it make it a greater work of difficulty to maintain the

extemporized cabin on board this model at the steady level than there would be in the ponderous and slowly-moving saloon of the Channel ferry. It may also be pointed out, that, in actual working, the cabin would in all probability be free from the disagreeable tremulous motion observed in the model, and which is due to its extreme lightness, to the position of the floor above the point of suspension, and a faulty arrangement of the pipes connected with the hydraulic presses.

Although a certain amount of doubt attached itself to this scheme of Mr. Bessemer, which only the actual experience of every-day practice can decide, the fact that he has taken the initiative in the matter of Channel transit improvement will earn for him a universal public gratitude. The hundreds of thousands of travellers who now endure the sufferings and inconveniences of the present service, will be sufficiently thankful even in the unlikely event of the Bessemer saloon proving a failure. For even in such a case they would be enabled to cross rapidly and in comfort, in vessels of such a size and form as to be comparatively little affected by the trying Channel seas, whilst the shock of waves striking against the sides will not be transferred to the passengers within the saloon, but will be absorbed by the framing of the vessel. The project of Messrs. Reed and Bessemer, to place such a service between Dover and Calais, is in all respects one which will be an incalculable benefit to the travelling public, and necessarily a profitable undertaking, whilst the introduction of the steady saloon is at least an experiment of the highest interest, and one which may in the future go far to modify the internal arrangements even of our ocean-going steamers, and mark an epoch in the history of passenger steamship navigation.

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—A regular meeting of this Society was held at its rooms in New York on Wednesday evening, November 20th, 1872.

Mr. F. Collingwood read a paper on "Alcohol as an Illuminator in a condensed atmosphere"—giving account of a comparative experiment made in the West Caisson of the New York Bridge, with alcohol and candles to test their relative illuminating power under a pressure of 31 lbs., and at a temperature of 80 deg. Fahr.

The lamp had a loose cotton wick ¼ in. in diameter; the base of the flame was 2 in. above the surface of the alcohol; the candle, of stearine, was 1¼ in. in diameter.

There was consumed per hour—under pressure—6 cubic in. of alcohol, and ⅝ oz. of stearine; and in the open air 2 cubic in. of alcohol, and ⅛ oz. of stearine.

In the condensed atmosphere the lamp burned with a clear, bright flame—not blue—without smoke, and gave ⅔ as much light as the candle, which smoked greatly.

Taking into account the waste of stearine by flaring, and short pieces not burnt—with alcohol at $2 per gallon and candles at 28 cents per lb.—for an equal amount of light, that from alcohol costs about twice as much as that from stearine.

It is suggested that a mixture might be made of alcohol and some carbonizing fluid to burn without smoking in a condensed atmosphere—the proportions to be varied to correspond with the change of pressure.

A paper by Mr. T. Guilford Smith on "Coal-Cutting Machinery in England under the Present Prices of Coal" was read, which presented the observations of the writer during the late great rise in prices of coal there.

The efforts made in England to cut coal by machinery had not met with much encouragement until a comparatively recent date, when the demand for coal, increasing beyond precedent, gave the miners a chance to strike for higher wages.

For some time there has been an increasing and alarming difficulty in obtaining a supply of coal at the great trade centres, caused by disputes about working hours, the colliers' strikes, the demand in new iron districts and in foreign countries.

In July last, London prices of coal were from 24 to 32 shillings per ton. Commenting upon this, the "London Evening Standard" said: "A suggestion has been made of which we heartily approve: that the exportation to foreign ports might be to a certain extent checked by a reasonable export duty on the material which has been called the third necessity of life:—the order running—bread, meat, coal. We may rely upon it that, whatever impost we lay, the Russians would still be our customers; but, in addition to them and the Germans, the French, the Spaniards, the Austrians, the Italians, the Egyptians, and even the Americans come to our markets. The French and the Italian governments coal their steam navies from our mines, so do most of the great trading companies of the Continent, and the principal packet lines. It is we who set going the locomotives of the Indian, of the Swedish, of the Danube and Black Sea, of the North Russian and of the Egyptian railways."

To determine the merits of the various coal cutting machines naturally resorted to in this emergency, as a saving of hand labor—a competitive trial has been proposed, to take place at an early day.

Probably no machine will in all cases be the best, and doubtless many changes will be requisite to adapt an English machine for use in American mines.

The cost of coal-cutting in England varies from ⅛ to ¼ the total cost of mining.

Several machines were described at length. One, costing £160—driven in pairs by air compressors costing £500—is said to do the work of 40 men in a 2½ or 3 ft. seam; it is 6 ft. long and 2½ ft. wide, and

carries at one side a horizontal arm, around which passes an endless chain provided with strong steel cutters; these cut at the rate of 45 ft. per hour.

Another machine, operated by hydraulic pressure, will by means of a series of reciprocating cutters, arranged upon a horizontal arm, cut 15 yards per hour, 4 ft. into or under the coal, at any height or angle. It is claimed that with this machine a seam will yield 1,000 more tons of coal per acre, than when worked in the usual manner.

A third machine, costing £150 and also driven by compressed air, has cutters arranged like saw teeth around a horizontal wheel 3½ ft. in diameter, which cuts into the seam 3 ft. in depth. Its regular night's work was a groove 120 yards long, 3 in. wide and 34 in. deep—the proportion of slack to coal being but 1 to 10.

Other machines similar in character were mentioned—also a rock drill, invented by Gen. Haupt of Penn., which after 22 modifications is now capable of drilling a 2 in. hole in granite, 6½ in. per min.

Should the prices of coal quoted continue for any time, our American fields may have a chance to ship their products into new channels, Nova Scotia having already taken the lead. In October orders transferred from Liverpool, England, were received in Georgetown, D. C., for large quantities of Cumberland coal to be shipped to Bombay, Aden, Egypt, Rio Janeiro, and various foreign ports.

Mr. J. Dutton Steele remarked through the Secretary: "Coal-cutting machinery has not thus far been introduced into this country. The operation of cutting coal is chiefly confined to cutting a deep groove or channel in or under the veins so that the miners may pry down the coal that is above it. Generally but one such groove in a vein is required; the cost of cutting per ton of coal will therefore be inversely as the thickness of the veins. The English veins referred to are 2 ft. 10 in. and 2 ft. 4 in. thick. Workable American bituminous veins are from 4 to 8 ft. thick, and our anthracite veins from 20 to even 50 ft., which will account to some extent for our indifference relative to coal cutting machines.

"There is another reason: powder is freely used by our miners; it is less work to blast out the bottom of the veins, than to cut under them, but more wasteful; if powder represents the minimum of labor, cutting under represents the minimum of waste; nor is waste the only objection to the use of powder, it vitiates the air, and occasionally sets fire to the mines.

"With cutting machinery, compressed air as a motor will be introduced into the mines, whereby the ventilation will be improved, and the liability to fire reduced. In the anthracite regions, pumping and hoisting engines, with their steam boilers, are put under ground, and shafts cut out hundreds of feet above them for the escape of smoke and steam. Inextinguishable fires in the mines are the direct result of this practice.

"Steam should be made upon the surface, and there used to compress air to drive the engines below.

"I think machines working by impact are preferable to those having rotary cutters. One weighing 600 lbs. and supplied with a circular inch of air at 50 lbs. pressure per sq. in., will strike 300 blows per minute, each with a force of 300 lbs.; and with suitable cutters, it should cut under rapidly. By changing the cutters the machine could drill ranges of holes which would aid in breaking down the coal. Thereby the waste, liability to fire, and the cost of mining would be largely reduced and the mining interests be more independent of labor."

Mr. Miles Coryell remarked: "Without doubt coal-cutting machinery, when further developed and perfected, will be useful in mining bituminous coal,—it, however, does not seem applicable to the hard anthracite veins of this country.

"It is hoped that the use of steam or compressed air, wherever it can take the place of manual labor, will aid in subduing the lawless spirit among the miners, who now work and control our mines.

"Mine owners generally are not sufficiently interested in improvements, and do not appreciate the need of a cheaper, safer, and less wasteful system, which, with wise encouragement and moderate pecuniary aid, would surely be developed.

"In anthracite mines, the seams are irregular, and the coal of variable hardness, sometimes interspersed with sulphurets, which resist almost any cutting tool. The diamond drill has been profitably used for drilling long holes between 'breasts;' with it, openings can be made through which noxious gases will escape; it is also of service in determining the position and depth of veins.

"More attention should be paid to improving the means of transportation in the mines; a locomotive, with large steam capacity, might be economically employed to draw the cars by day, and to drill holes for mining by night."

The Secretary exhibited models and drawings of machines for boring and drilling rock, and specimens of work done, and explained the methods and stated the cost of operating each.

Professor Devolson Wood generally reviewed the history of rock drilling by power; he also noticed the difficulties surmounted and yet to be overcome, and the results already secured.

A discussion followed, participated in by most of the members present. The subject of coal cutting and rock drilling by power will be taken up again at a future meeting. Members and others are asked to communicate meanwhile to the Secretary, for presentation then to the Society, whatever professional experience they may have in the matter.

A regular meeting of the Society was held at its rooms in New York, on Wednesday afternoon, December 4th.

A paper was read upon "Rail Economy" by C. P. Sandberg, C. E., of London, in which, under the three heads—Iron Rails, Steel Rails, and Traffic Capacity—the author deals with the saving that may be effected in the item of Railway Cost.

Iron Rails.—The American demand for English rails, of say 500,000 tons yearly, is unlikely to diminish soon. The late increased expense of iron adds to the cost of railroad construction, and tends to reduce the quality of rails. Welsh rails were often imperfect in weld—now they are sometimes also brittle. In the Cleveland district, rail making has greatly improved, chiefly by the increased application of fettling in the puddling furnaces.

Still the buyers must guard against lamination and brittleness by tests for strength and wear, applied before the rails are laid. Rails made of suitable iron, with a proper section, will not break in winter; in Scandinavia, with a climate more se-

vere than in America, no accident has occurred from broken rails, though cross sleepers are exclusively used. But a very small portion of the iron rails shipped to America will stand the proper tests.

No late improvement promises so much to perfect iron rail making, as mechanical puddling, which now seems to be an entire success Among the best appliances for this purpose are those of Danks and Spencer: one producing the whole charge in one ball, and the other in several small ones. By this improvement more rails can be made, at a reduced cost and of better quality.

Steel Rails.—The demand during the past year has been so great for steel rails, that they can hardly be obtained at any price; the supply is limited by the lack of ore free from sulphur and phosphorus, and recourse has been had to extensive mines in Spain. It is hoped that America will supply herself with steel rails, and import only those of iron required for new lines or light traffic. There is a scarcity of suitable ore for the Bessemer process throughout Europe, except in Sweden, which the recently discovered coal there will render more available.

The Siemens-Martin process of steel making—superior to the Bessemer in requiring a less pure ore, has thus far produced so little that it can hardly be called a source of supply in the great market.

Steel rails are now so well made that they rarely break, except when the flange is punched, and this should be done only while the metal is hot, or the notch drilled and then slotted. Although a steel rail is generally thrice as strong as an iron one, when punched or the flange is cracked, the iron may be the stronger. The steel is made as soft as possible, say with $\frac{1}{4}$ per cent. of carbon,—for not by hardness, but by homogeneity is it superior to iron.

Usually a steel rail will carry $\frac{1}{3}$ more dead load than an iron one; hence, for the same traffic, the steel rail, in comparison with the iron, should not be reduced in weight more than 20 per cent.

Buyers should require each rail to be permanently marked to indicate date, maker's name, and quality, that subsequent use may determine which manufacture is best.

Traffic Capacity.—The amount of wear or life of a rail is usually expressed in tons passed over it before rejection; properly the speed of travel should be taken into account, and 220,000,000 speed tons is a fair expression of the endurance of extra iron rails.

The average life of iron rails in England for ordinary traffic is about 10 years; in and near London it is 2 years or less; on the Continent from 12 to 15 years; and in Sweden—with less traffic than in England—from 15 to 18 years.

The weight passed over good iron rails before rejection, has been found to average 10,000,000 tons; this may be taken to represent the life of extra iron rails—and 6 times that the life of good 56 lb. steel rails. On the "London and Northwestern Line" steel rails have lasted 20 times as long as iron, and on the "Metropolitan Railway," with the greatest traffic in the world, where iron would not have lasted 6 months, steel will stand from 3 to 4 years

In comparing the relative economy of superior iron rails, and those of steel, prices of each per ton being taken at £7 and £11, and interest on capital 5 per cent., the yearly saving per mile would be £4 where iron rails would last 15 years, and steel were used; £10 where they would last 10 years, and steel were used; and £78 where the iron rails would last but five years, and steel were used.

A table was given showing the gross load in tons which each quality and weight of rail may be expected to carry during its life, and the conditions were stated therewith to aid in the selection of rail to accommodate a given traffic; an important matter, since many European railways are laid with too heavy rails, and American with too light ones. Equally important with the weight of a rail, is a proper section. In England the double-headed rails are still generally used, and elsewhere in Europe, the flat bottomed pattern, as also in America. A specially bad section is the Erie 61 lb. rail, which could be replaced by a 45 lb. rail, well proportioned.

Prof. Rankin says the weight of the rails per yard in length should equal 15 times the greatest load on the locomotive drivers in tons. Perdonet, in France, takes 12 in place of 15; the writer, by adopting a section which permits a fish-joint stronger than the others in general use to be made, takes 10 and less; thus for a 60 lb. rail. the weight on drivers is put at $6\frac{1}{2}$ tons. Fish plates of steel will enable rails to carry from 15 to 20 per cent. greater load than if iron were used of the same section; they will cost, per ton, about $8 less than steel rails, and the iron about $1 more than iron rails; hence the adoption of steel fish plates will be of benefit even with iron rails.

Mr. Macdonald remarked that Mr. Sandberg, in taking $6\frac{1}{2}$ tons weight per locomotive driver as a safe load on a 60 lb. rail, differs from the best practice in this country. The Philadelphia and Reading R. R., on rails made with great care by the Company, prefers not to exceed 4 tons on a 64 lb. rail—and the rail section has been gradually increased to counteract wear and tear from even this medium load.

On the Erie railway $5\frac{4}{10}$ tons weight on drivers has been found too great for best 70 lb. iron rails—and with a speed, for heavy freight trains, of 15 miles per hour, should not exceed $4\frac{1}{2}$ tons.

Mr. Allen remarked that this was of great personal interest to him; his first railway report dealt with the question of weight upon drivers, and showed the need of keeping it below certain limits. If greater weight is to be carried, the number of drivers should be increased; and the time will doubtless come when locomotives with 8, 10 and even 12 drivers, will be used. In no way has more money been wasted in the construction and operation of railroads than by increasing the weight upon drivers, to the great injury of roadbed, rails, and rolling stock.

IRON AND STEEL NOTES.

BARRON'S STEEL PROCESS.—Barron's process for the manufacture of steel tools—or rather for the conversion of iron tools into steel—is now in successful operation in Louisville, Ky., where it has attracted no little attention, and has met with very encouraging success. Tools which are to be prepared by this process are first made of cast iron, after which they are introduced into a revolving

drum, where the roughness and adhering sand from the moulds are worn off by attrition The smooth irons are then packed in layers in iron boxes, where they are closely imbedded in clay, and subjected to the action of oxide of iron and certain chemicals, by which the iron is decarburized. There seems to be a secret connected with this part of the process. In these boxes the iron tools are subjected to annealing heat, which is maintained for from three to six days. They are subsequently placed in a retort capable of containing about a ton of the tools, into which the vapor of gasoline and other carbonaceous materials is passed. In a few minutes the iron is transformed into steel, when they are ready to be tempered, and ground and polished for the market. The explanations of this process which we have seen are not as clear as they might be, but of the quality of the steel thus produced there is very little question. Professor J. S. Newberry, of the School of Mines, Columbia College, New York, referring to this subject, says: "With tailors' shears cast in shape, made malleable, and then converted by the Barron process, I have cut Florence silk so nicely as to prove the edge perfect; then, with the same shears, have cut up sheets of tin and untempered steel; returning to the silk have found the edge wholly unimpaired, and this after a repetition of more than twenty times. By whatever process steel of this description is made, its exceeding value must create for it a wide demand, and soon render the method by which it is made widely celebrated. —*American Exchange and Review.*

ONE hundred thousand tons Lake Superior tonnage will be added for next season, thus affording facilities for the transportation of no less than 1,000,000 tons of ore above this year's shipment. Limited transportation and dock facilities have caused, to a great extent, the high price of ore and pig. The contemplated extension of such facilities will, no doubt, go far to keep these products at their true level.—*Iron World and Manufacturer.*

MAGNETITE IN SPAIN.—Mr. Mack, British Consul at Malaga, writes of the Spanish iron ores, that it is a subject of dispute as to the relative merits of these ores for the smelting purposes of the present day, as to which, for example, is most suitable for the Bessemer process—the test most generally applied. There are two most magnificent lodes or deposits in the district of Malaga, calculated to be of inexhaustible proportions. The first has supplied two large and important smelting works, with their corresponding rolling mills, for the last 30 years. The smelting has been carried on with charcoal from Spain and Tuscany, and the effect upon the deposit, although the extraction has been large, appears insignificant. The iron which has been produced has been always of the very finest quality and singularly malleable; so much so, that it has generally, for some purposes, been puddled up and mixed under the hammer with a certain proportion of harder English pig iron imported for the purpose. This mine of magnetic ore belongs to two parties—half to a wealthy resident Spanish house, and the other half was purchased by an English firm from Glasgow; and they have since constructed 3½ miles of railway down to the sea, with a handsome iron pier sufficiently large to accommodate steamers of 1,000 tons to load alongside. They have since formed a company with £300,000 capital, and have started fairly at work. The mine is half way between Malaga and Gibraltar, at a place called Marbella, the importance of which will be greatly increased in a few years. The other discovery is quite recent, and although its vast proportions and merits are fully acknowledged, it has not yet been worked.—*U. S. Railroad and Mining Register.*

RAILWAY NOTES.

CHANGE OF RAILROAD GAUGE IN CANADA.—The broad gauge on the Grand Trunk Railway between Sarnia and Fort Erie, a distance of 200 miles, was changed on November 17th, from 5 ft. 6 to 4 ft. 8½ in. All the trains arrived on the following day on the regular time bill.

This change makes the Grand Trunk track uniform with that of the New York Central, Michigan Central, and other connections of the Grand Trunk Railway. It will undoubtedly prove of great advantage, not only to the companies concerned, but also to the travelling public, and shippers of freight to the West. Practically it creates a new through route, of unbroken gauge, between the East and West, by way of this city and without the intervention of ferries, on the completion of the International Bridge across the Niagara River at Buffalo, and the tunnel under the bridge across the Detroit River. The Buffalo bridge will undoubtedly be finished next summer, and the other great works will be pushed to completion without delay.

A NEW RAILROAD IN MASSACHUSETTS.—Surveys have been made for a road from New Bedford to Fall River, a distance of about 14 miles. The present connection between these two towns, by way of the New Bedford and Taunton and Old Colony roads, is very indirect, being about 26 miles long.

ENGINEERING STRUCTURES.

THE TUNNEL UNDER THE MERSEY.—In May last the sinking of a shaft was commenced at Woodside, and after passing through 65 ft. of red sandstone and pebble-beds a depth of 85 ft. has been reached, which corresponds with the level of the headings of the tunnel. The floor of the tunnel is 9 ft. lower, but this depth will not be taken out until some progress has been made in running the headings under the river. The material cut through was found to be firm, and so little provision is needed for drainage that a 6 in. steam pump is adequate to keeping the cutting dry. In the meantime endeavors have been made to ascertain the character of the material through which the tunnel is to be carried. Borings have been taken at every three chains almost the whole width of the Mersey. From Birkenhead to within 300 yards of the Liverpool side it was found that the river bed was red sandstone, but at the latter point a bed of sand 10 ft. deep was found to lie on the rock. Borings on the land side would seem to indicate that this rock continues from end to end, and therefore there is not likely to be any especial difficulty in the construction of the tunnel.

AN OLD THAMES EMBANKMENT WALL.—In excavating for the foundation of Mr. de Keyser's new Royal Hotel, Blackfriars, a fine specimen of masonry has been discovered, which Mr. E. A. Gruning, the architect of the hotel, considers must have been constructed in the fourteenth century. It has a battering face of Kentish ragstone, backed with chalk and cement. It is about 4 ft. thick, and has its foundation on elm piles, 16 in. square and 12 ft. long, timber 6 in. thick and about 2½ ft. wide, being laid as a platform on the piles. The wall had no coping. A length of about 150 ft. of the wall has been removed to admit of the construction of the new building. Outside the wall was the remnant of a landing-stage, of a triangular shape, with foundations of the same character as the wall itself, and there were stairs to this landing-stage. The upper part of the masonry was too much destroyed to enable one to form a very distinct idea of its appearance. Outside the wall was also a quantity of foreshore river shingle. The ground inside has been supplied at various dates, and contains hardly any objects of antiquity. At the western end of the embankment wall there was a projecting bay, in the shape of an octagon, the facing of it being as perfect as when it was executed. Inside the wall is another wall of brick, resting on short piles, with pointed arches springing from the piles.

CANADIAN capitalists have determined to cut a canal through the narrow neck of land which connects the provinces of New Brunswick and Nova Scotia, capable of allowing the passage of the largest trading vessels. While the distance to be accomplished is only 16 miles, there are difficulties to be surmounted which will severely tax the skill of the engineer and contractors. The worst of these obstacles are the tidal fluctuations, neap tides rising in the Bay of Fundy 38 ft., and the Bay of Verte only 5 ft. The advantages to trade will be many. Direct water communication will be had between the upper and maritime provinces, and both Ontario and Quebec will be enabled to send their produce into the Bay of Fundy and even to New England ports at much less cost.

ORDNANCE AND NAVAL.

A MARINE BRAKE.—M. Raffard has presented to the Société des Anciens Elèves des Ecoles d'Arts et Métiers, a note on a brake which he has devised, having for its object to diminish the rolling of vessels. This apparatus would insure, according to the inventor, firstly, a more exact draught; secondly, the power of inclining the vessel on one side, so that the non-armored parts of the hull should not be exposed to an enemy's fire, besides permitting repairs to be made on the other side; thirdly, the advantage of reducing the height of the immerged part of the armor; fourthly, it would prevent a ship from excessive rolling in bad weather.

These results are to be obtained by the aid of two floats situated one on each side of the vessel, at about 5 ft. below the water line, which can be moved at will and turn around a horizontal shaft. These species of wings, or rather fins, are connected by rods to a piston working in a steam cylinder, and they are coupled together in such a manner that they may be horizontal at the same time, and that their movement of rotation may be in opposite directions. By working the controlling lever of the steam cylinder, a rotary motion is imparted to the fins, resulting in an artificial rolling of the ship, and it is to be understood that the man in charge following with his eyes the movement of the ship, can manœuvre this artificial rolling in such a manner as to neutralize or to reduce more or less (especially less) the natural motion of the ship.—*Engineering*.

BOOK NOTICES.

NIAGARA, ITS HISTORY AND GEOLOGY, INCIDENTS AND POETRY, WITH ILLUSTRATIONS AND MAPS. By GEORGE W. HOLLEY. New York: Sheldon & Co.

The impression produced by this volume, as compared with ordinary guide-books, is similar to that produced by Tyndall's "Hours of Exercise in the Alps," as compared with ordinary newspaper sketches. It will doubtless supersede the meagre and unsatisfactory Niagara Guide-Books heretofore published.

The work is well presented, with clear, open type, on tinted paper, and is of a very convenient size. The arrangement of the matter is excellent, though some confusion may arise in the mind of the careless reader, from the absence of the word "Local" from the general heading of a portion of the pages in Part Third.

We have in *Part First* a succinct and graphic general history of the River, Falls, and surrounding country, with a notice of the first white men known to have visited them. *Part Second* contains a full and interesting exposition of the geology of the locality, including the birth and age of the great cataract. The descriptions of the ancient Niagara barrier which formed the eastern shore of an immense inland sea extending west to Lake Superior, and of the winter scenes and phenomena at the Falls and along the river, are particularly original and striking. So also is the sketch of the geognosy of the earth's surface from the Gulf of St. Lawrence to Lake Huron—represented in profile on the map—showing the remarkable fact that the water from the springs in the bottom of Lake Huron rises perpendicularly more than 500 ft. higher than the Lake to the Gulf.

Part Third is devoted to the local history of the Falls and vicinity, and the incidents and accidents connected therewith. It is enlivened by divers curious relations and anecdotes; those concerning the Indian Chief Red Jacket are characteristic, and will illustrate his tact and shrewdness. The chapter giving a biographical sketch of Mr. Joel R. Robinson, who took the steamer "Maid of the Mist" through the whirlpool and down the gorge to Lewiston, will make the general public acquainted with a remarkable man. The description of this voyage is a most stirring bit of narrative. We cannot resist the temptation to copy for the consideration of scientific readers, a singular phenomenon said to have been noticed near the Great Railway Suspension Bridge in the year 1863. The author says: "A mass of rock and shale about 50 ft. long, 20 ft. wide, and 60 ft. deep, fell with a great crash on to the hard bed of the river. Di-

rectly following the fall, a remarkable motion was developed in the bridge itself. A strong wave of motion passed through the whole structure from the American side to the opposite shore, and returned again to the same side. Some 12 or 15 mechanics who were at work on the upper or railway track were so alarmed that they fled with all speed to the shore. The motion imparted to the bridge was incalculably greater than, and of a different character from, any motion imparted by the crossing of the heaviest trains. The rocky mass which fell was 40 rods below the bridge, and the hard floor on which it struck, more than 230 ft. beneath it. The mass itself fell about 60 ft. average distance, and might have weighed 5,000 tons. The extraordinary motion imparted to the bridge by the concussion, must have boen transmitted along the subterranean rock to the anchorages on the American side, thence through the cables and the bridge, across to the anchorages on the Canada side, whence it reacted or returned again to the American side.'

Part Four is devoted to the rhythmetic utterances inspired *or perspired* by the great scene. The first portion of it may be called the nonsense rhymes of Niagara, while in the latter portion we have the more serious and impressive lines—and they are few, indeed, which have been deemed worthy of preservation. Many readers, however, will miss Mrs. Sigourney's oft quoted verses, from the collection.

Every visitor at the Falls will find the pleasure of his sight-seeing greatly enhanced by reading the book among the scenes which it so pleasantly describes.

THE SLIDE VALVE BY ECCENTRICS. By Prof. C. W. MACCORD. New York: D. Van Nostrand.

From such examination as we have thus far made of the proof-sheets of this new book it seems admirably adapted to the wants of students laboring in this department of technical science, whether with or without an instructor.

The scope and design of the work are thus set forth by the author in his preface.

"The action of the slide valve of the steam engine, operated through various intervening devices by a motion derived from an eccentric, has been so often and so ably discussed, that in presenting a new treatise on the subject, an explanation seems called for, offering an excuse for its appearance. The object of the present work is that of aiding practical engineers in forming a clear idea of, first, the nature of the motion, and what the valve can be made to do; second, the requirements of the engine, and what the valve *must* be made to do; and third, the construction of the movement and how to make the valve do what it is to do; and the plea for its existence, upon which main reliance is placed, rests primarily on the manner in which these questions are presented.

"Much labor and zeal have been expended, not to say wasted, in treating this matter analytically,—the method being to embody the elements, constant and variable, of the whole combination, including all the connecting rods, cranks, eccentrics, rock shafts, and levers making up the working gear interposed between the piston and the valve, in an equation expressing the movement as influenced by them all; and by discussing this equation to deduce results as effected by various supposed changes in the proportions or relations of the elements.

"The subject affords a good field for the display of analytical acumen, and this method of employing algebraic skill for a practical purpose is at once elegant and refined; but such investigations do not answer the purposes above set forth: admirable as they may be intrinsically, they are so mainly to the select few as interesting studies of applied mathematics. It must be borne in mind that of those who study closely the mechanical movements of the steam engine, particularly those who are directly interested in the practical matter of engine building, the draughtsmen who design as well as the mechanics who execute, the great majority are not versed in the higher mathematical branches. And more especially is it true, that they are seldom of the order of mind which turns naturally to analysis as a mode of solving problems, the *geometrical* reasoners and the ones most likely to adopt a profession in which graphic methods are in constant use: and to many, proficient in these, anything written in the language of symbols is a sealed book.

"Again, the connection between an abstract formula and its concrete embodiment is so indirect and obscure, that even those competent to trace the equation through its various transformations from the initial to the final stage, have frequent need to resort to graphic methods of illustrating their progress, and are absolutely driven back to them in order to construct their ultimate expressions, and reduce their theoretical deductions to a practical form.

"It is to be considered, too, that the engine itself is not a creature of analytical instincts,—its parts move with geometrical precision in lines and about centres which, having fixed linear relations to each other, are just as susceptible of accurate delineations on paper as of accurate adjustment in metal; they did so before their motions were analyzed, and would continue to do so to the end of time, though the act of analysis were forgotten. In fact, the mathematical education of the engine has never gone beyond geometry; it was planned by geometry; to be sure you may examine it analytically and formulate its results, but, algebra or no algebra, it will answer no questions which it cannot answer by geometry.

"Since the valve movements must eventually be constructed by graphic process, whether they be previously discussed analytically or not, there seems to be no good reason why the former method should not be separately used in the whole investigation. On the contrary, it would appear from the preceding considerations that it is peculiarly adapted, not only to the elucidation of this subject, but to the tastes of those specially addressed; it has therefore been adopted, to the entire exclusion of algebraic analysis, which those who prefer it may find exhaustively used in other works.

"In regard to the general arrangement and subdivision of the matter presented, it is proper to remark that, in the author's opinion, the chief source of the difficulty often found in imparting, even by the graphic method, a thorough insight into the action of the slide valve and the construction of its movement, is to be found in the fact that usually the investigation starts out with the three-ported or common slide, very often miscalled, 'the sim-

plest form of the valve,' and introduces at once the several adjuncts of 'lap,' 'lead,' 'inside clearance,' etc., which, though simple enough when separately considered, are bewildering to the beginner when he is at once confronted with them all.

"By dissecting this valve, and considering its members and their functions, one by one, the author has endeavored to make their combined action more readily comprehended."

The subjects separately treated in chapters are as follows:

1. General investigation of eccentric motion.
2. Of the action of the valve as applied to a single steam port.
3. The action of the exhaust valve; of the three-ported or common slide valve, and of the two-ported or box valve.
4. Of independent cut-off valves.
5. The angular vibrations of the main connecting rod and the eccentric rod.

A POPULAR TREATISE ON GEMS IN REFERENCE TO THEIR SCIENTIFIC VALUE. By Dr. L. FEUCHTWANGER. New York: Published by the author. For sale by Van Nostrand.

This excellent work has reached its fourth edition. A portion of the older edition has been rewritten and an appendix added containing among other interesting matter a tabular classification of the characteristics of the leading gems.

Aside from the value of this book to the mineralogist and the lapidary, who have long been familiar with it, the interest that attaches to the subject, and the fulness of the information afforded to the general reader, will together create a larger demand for the work than its technical utility.

The present issue is in a prettier dress than the former editions, as if in deference to the many who will consider it a valuable addition to a library of general literature.

MANUAL OF LAND SURVEYING, WITH TABLES. By DAVID MURRAY A. M., Ph. D. New York: J. W. Schermerhorn & Co.

This neat little manual of surveying contains just enough of the elements of the science to constitute "a course" for the academies and high schools. It is, moreover, of such convenient size as to be easily carried by the practical surveyor who desires to consult formulas and tables in the field.

Besides the usual matter relating to land areas, topography, levelling, etc., the author has added chapters on "underground surveying," "the use of the plane table" and "the construction and use of the solar compass."

The book is neatly printed and has an abundance of illustrations.

A FIRST BOOK OF MINING AND QUARRYING, WITH THE SCIENCES CONNECTED THEREWITH, FOR USE IN PRIMARY SCHOOLS AND SELF-INSTRUCTION. By J. H. COLLINS, F. G. S. With Numerous Illustrations. London, 1872. For sale by Van Nostrand.

This little work is intended much more to show what has to be learnt by the miner and quarryman than to impart actual knowledge. Still, a good deal of useful information will be found in its pages. We have observed a sentence or two about blasting with gunpowder, but no hint as to the variety of blasting-powders lately coming into use, such as dynamite, pudrolithe, etc. The author, however, must be well enough acquainted with the subject, as he is lecturer to the Miners' Association of Cornwall and Devon.

LA CONSTRUCTION DES PONTS ET VIADUCS. Paris: Eugene Lacroix. For sale by Van Nostrand.

This elegant quarto contains the most complete set of Illustrations of bridges we have ever seen. Bridges and viaducts of wood, stone, iron and steel, in all quarters of the globe, are represented by fine lithographic plates.

In the case of noted structures the details are exhibited on an enlarged scale. Foundations of wood, stone and iron, are elaborately treated, and in some instances the method of construction is elucidated by exhibiting the different stages of progress in construction.

There is but little of explanatory text, scarcely more than would suffice for a full index, but the completeness of the illustrations compensates fully for lack of other description.

The work is divided by the classification of the compiler into 3 parts, making as published 5 volumes.

ELEMENTARY TREATISE ON NATURAL PHILOSOPHY. By A. PRIVAT DESCHANEL. Translated by J. D. EVERETT, M. A., D.C.L., F.R.S.E. In Four Parts, Part IV. London: Blackie & Son. For sale by Van Nostrand.

This is the fourth and concluding part of this excellent elementary treatise on natural philosophy, and deals with Sound and Light, which are treated in the same concise and clear manner which we found in the other branches of science in the preceding parts. Professor Everett, however, has found it necessary to re-write whole chapters, such as those on Polarization, the Undulatory Theory, and Color, adopting the latest researches of Helmholtz and Clerk-Maxwell as the basis of the latter. Throughout this part, too, Professor Everett has thought it advisable to supply fresh matter here and there, so that the book might be brought up to the present state of scientific knowledge. The complete book of four parts contains altogether 1,050 pages, 760 beautifully engraved and printed wood-cuts, with three colored plates. For perspicuity of style it is not surpassed by any scientific book with which we are acquainted, and no work contains so much information in so small a compass, considering the clearness and the elegance of the printing. A book like this is a first-class prize for the cleverest pupils in elementary schools, and forms a handsome and valuable Christmas or New Year's present.—*English Mechanic.*

HEALTH AND COMFORT IN HOUSE BUILDING; OR, VENTILATION WITH WARM AIR BY SELF-ACTING SUCTION POWER. By J. DRYSDALE, M.D., and J. W. HAYWARD, M.D. London, 1872. For sale by Van Nostrand.

In a previous volume we printed part of a paper by Dr. Hayward, read at a meeting of the Liverpool Architectural Society, descriptive of a house built by him, with special arrangements for warming and ventilating. The volume now before us is an elaboration of this paper, made in conjunc-

tion with Dr. Drysdale, who had previously erected a house in the suburbs of Liverpool, in which he had attempted to meet many of the defects of ordinary houses. The scheme worked on may be said to be, plenty of fresh air admitted to a heating chamber in the lower part of the house, and thence supplied to the various rooms through openings in the cornices; the collection of the foul air from the various rooms, into a foul-air chamber formed in the roof, whence it is taken down to the kitchen fire, and passed off to the air by an air flue formed round the smoke flue. The due adjustment of the openings for admission and emission, and the prevention of accidental ventilation which would interfere with the results of the calculations, of course come into discussion as difficult portions of the problem to be solved. All the flues, as they are provided for a probable maximum, attained only on extraordinary occasions, must be controllable by valves. The difficulty of "squaring" all the antagonistic circumstances must be great; nevertheless the authors state as the result of practical experience, that "in the houses erected in accordance with these data, the whole scheme works with an accuracy quite sufficient for all the requirements of practical utility." In an appendix the various methods of calculating draughts in hot air flues are reviewed, several formulæ being given, and there is a record of some original experiments performed in one of the houses. The volume will be found of value by those who know how to use it.

MISCELLANEOUS.

THE "Gorni Journal of St. Petersburg" gives some interesting notes on the production of gold and platinum in the Muscovite empire. In 1868 were produced (in 993 gold stream works, by 56,261 men, from 14,365,550 tons of gold sand) 56,068 lbs. of gold, the raw sand yielding 0.000195 per cent. on average. The greater part was washed in Eastern Siberia, where the richest stream works exist. At the Government gold diggings, or stream works, near Miask, in the district of Stataoust, the gold bearing stratum of sand is about 2½ ft. to 3 ft. thick, covered by 15 feet of dead gravel. The uncovering of the beds and the delivery of the gold sand to the washing establishments is generally done by contract and by the cubic fathom. The raw material is first screened in a stream of water, when the small parts flow through ¾ in. sieves upon buddles with transverse wooden laths, behind which the gold particles principally collect. Every 6 or 12 hours, according to the produce of the sand, the laths are removed and the table washed clean with scrapers, brushes, etc., of this concentrated material, while larger lumps of gold are collected upon the screen from between the larger pebbles. At the larger works the extraction of the metal from the concentrated sand is done by steam power, when the sand is washed through a fine sieve upon a buddle with American frame, where the stuff is still more concentrated, and finally finished upon hand washing machines. When the raw sand contains much clay or loam, perforated rotating drums are used instead of simple screens. The washed gold generally contains 10 per cent. of silver. Where only hand power is used 40 men will wash in 10 to 12 hours 40 to 60 tons of sand, while with the use of machinery 150 men and 50 horses will wash 8 or 10 times that quantity. The greatest and most productive gold-fields of Russia will always be those of Siberia. Platinum is always washed together with gold, and the production of raw platinum rests finally upon a separation from gold, with the exception of a single locality. The mixture of gold and platinum which is brought to Tagilsk is classified in two sorts. Both are treated with mercury when the gold is dissolved, while the platinum is left as a residue, which is separated from the amalgam by washing. The latter is pressed through a leather bag, and the gold obtained by distilling off the mercury. The raw platinum is by no means clean, but some samples contained, after M. Le Play, other metals, such as platinum 75.1, palladium 1.1, rhodium 3.5, iridium, 2.6, osmium-iridium 0.6, osmium 2.3 gold 0.4, copper 1.0, iron 8.1, residue 4.5. The raw platinum is generally sold to England and France at a price of £15 per lb. platinum. The production of this metal was from 1828 to 1845, 5,247 lbs. on average, and is now 4,000 lbs per annum.

PAPER CAR WHEELS.—It is stated that a Connecticut railroad is about to make a trial of the so-called paper car wheels. These wheels are costly, but run safely and easily; they have been known for some time to car builders, but their introduction into general use has been prevented by the expense. Sheets of common straw paper are forced into a compact mass by a pressure of 350 tons. The mass of paper is turned perfectly round, and by a pressure of 25 tons a hub is forced into a hole in the centre. This paper wheel, by a pressure of 250 tons, is next forced into a steel tyre with ¼ in. bevel upon its inner circumference. Two circular iron plates are then bolted on to the tyre to keep the paper filling in place. By this arrangement the steel tyre rests upon the paper only, and partakes of its elasticity. It is claimed that these wheels wear longer than those of any other description, injure the tracks less, and run with less noise.

ARTESIAN WELLS AT CHICAGO.—Artesian wells are multiplying in Chicago, 21 of them having already been bored, and in no instance has a failure to obtain a plentiful supply of water occurred. The well at Kenwood, just south of Chicago, 1,255 ft. deep, and 5½ in. diameter at the bottom, yields 650 gallons per min. It cost about 6,000 dollars. Another well, in the business centre of Chicago, is 1,600 ft. deep, yields 525 gallons per min., and cost 7,000 dollars. The usual depth of the wells is from 1,200 to 1,300 ft., and the average cost is 6,000 dollars for a 5½ in. well 1,200 ft. deep, and 5,000 dollars for a 4½ in. bore to the same depth. The surface pressure of the water varies from 22 to 35 lbs. to the sq. in., and the latter pressure is sufficient to throw a stream to the height of 100 ft. The deepest well in Chicago is in the South Park, where the bore, 3½ in. in diameter, has been carried down 1,640 ft. The comparative smallness of the flow from this well is adduced as an argument in favor of larger borings.